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An economic analysis of the resource structure of United States agriculture

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AN ECONOMIC ANALYSIS OF THE RESOURCE STRUCTURE

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CHAPTER 1: INTRODUCTION

Two basic aspects of the changing structure of U.S. agriculture are related to the two great agricultural problems of the world. The first world problem is found in underdeveloped nations -- malnutrition, disease, and consequent social and political discontent. The unparalleled success story of American agriculture has important ramifications and offers new hope for underdeveloped nations. Evidence of the "success" aspect of U.S. agriculture is apparent from the following statistics: From 1940 to 1960 total agricultural output in the U.S. increased 57 percent although total inputs increased only five percent. Output per unit of labor increased 210 percent in the same period. One farmworker supplied 10.7 persons in 1940, 26.2 persons in 1960. Increased labor productivity permitted large numbers of farmers to migrate to urban employment and increased the real income of society. The vast parts of the world beset with lethargic agricultural economies are as much (perhaps more) impressed with these accomplishments of American society as with the accomplishments in armament and space.

Problems of surplus and overproduction in American agriculture are dramatic evidence of capital accumulation, technological improvement and managerial success. Underdeveloped nations, eager for higher standards of living, wish to replicate the conditions causing structural changes in American agriculture. The conditions or setting for economic growth in American agriculture are in many respects unique and are not found in all countries. It is necessary to know more about the structure of agriculture before determining to what extent: (a) the conditions necessary for economic growth are found in underdeveloped countries, (b) these conditions can be induced, and (c) it is desirable to induce the conditions.

The second, more happy problem of world agriculture is overproduction and low relative returns to farm resources. This condition is found only in a few, highly developed countries. Evidence of the condition in the U.S. is apparent from the following statistics: Despite the 210 percent increase in farm labor productivity, real income per farm worker was only 77 percent greater in 1960 than in 1940. Moreover, average farm income per worker as a percentage of average income per factory worker declined from 66 in the first decade of the 1900's to 47 in the 1951-60 decade. The epochal structural revolution in American agriculture has brought vast benefits to society, but all segments have not benefited equally.

The two world problems of underdevelopment and overproduction have some features in common: (a) both are associated with low returns on resources, the former absolute, the latter relative, (b) both have become the focus of concern by policy groups, and (c) both have roots in the resource structure of agriculture. The resource structure is defined as the systematic framework of institutional, behavioral and technological relationships which determine output, efficiency and returns (income) in agriculture. This study is an attempt to derive quantitative estimates of parameters in the resource structure of U.S. agriculture. The study is largely oriented to the problems of American agriculture. But the pattern of U.S. agriculture embodies universal principals of economic growth, e.g. capital formation and technological changes. In one sense, the changing resource structure of American farms is a history of economic development. Each experience in development is unique, but it is hoped that knowledge of the resource structure of this country will have value for other nations as well.

Problems of overproduction and low incomes in U.S. agriculture are symptomatic of an underlying resource imbalance. Traditionally, government policies to control output and increase farm incomes have dealt with these symptoms rather than with the resource imbalance. As such, these policies have been short run. The basic assumptions of these programs is that the farm problem is acute rather than chronic, and that the price mechanism is capable of bringing needed long run adjustments. To most effectively determine what measures, if any, are needed to facilitate resource mobility in agriculture, more must be known about the resource structure.

To date, agricultural economics research has emphasized product markets. Economic studies largely have been superimposed upon the resource base, hence, are short run. Commodity studies have been useful, and current production controls reflect the empirical findings that demand for farm commodities is inelastic. That is, programs which decrease output increase farm income. But, programs consistent with economic efficiency and societal welfare cannot ignore the resource structure.

Much of the current policy debate is centered on the response of output to price in agriculture. The argument for free markets or strict controls centers on the slope of the output supply curve. Given the technology and weather, farm output is determined by resource levels. Since controllable changes in farm output depend fundamentally upon resource flexibility, knowledge of the input structure can help resolve conflicting policy arguments and provide the basis for programs consistent with the goals of society.

The ultimate goal of agricultural economic research should be a definitive, integrated model of the product and resource structure of agriculture. There are several reasons why an integrated model is necessary. Product markets determine gross income, resource markets determine expenses and the two markets determine net income in farming. From a causal and statistical standpoint, many decisions in farming are interdependent. It is not possible to determine how many hired workers, for example, will remain in agriculture without estimates of farm product prices, national unemployment and factory wages. To a considerable extent, farm input and output prices are determined by non-farm variables such as wage rates, national income and population. The mobility of farm labor is conditioned by the rate of national unemployment. Integrated models which include these non-farm variables are necessary for predicting farm income, output and efficiency.

Detailed studies (17, 25) have emphasized the totality and interdependence of farm product markets. A commentary on these studies is found in a recent stimulating article by Fox (36). Notable quantitative studies of the resource markets have been made by Griliches (44, 45, 46, 47), Heady and Yeh (57), Cromarty (23, 26, 27) and Johnson (74). These relatively few studies need to be supplemented and integrated with commodity studies to provide adequate knowledge of prices, quantities, expenses, income and efficiency in agriculture.

Objectives

The general objective of this study is to describe and analyze the resource structure of American agriculture. A major portion of the study is devoted to derivation of quantitative estimates of structural parameters determining farm resource allocation, output and income. Several specific objectives are to determine:

(a) the coefficients of variables in the major resource markets of agriculture over various periods of time,

(b) individual sources of historic changes in sources of demand, and projected future resource levels,

(c) the supply function for agricultural products estimated from input demand functions,

(d) the influence of non-farm wage rates, national unemployment, national income and interest rates on farm prices, expenses and income; and,

(e) the influence of various policy alternatives on farm output, income and resource allocation in the short and long run.

Procedure

The study is positivistic rather than normative. There is no assumption that the norm of farmers' behavior is profit maximization. The assumption of the positivistic models is that there exists a significant measure of repeatability in mass behavior. That is, if the underlying conditions in a situation are repeated (the exogenous variables have the same values), then the outcome (endogenous variables) can be predicted with a reasonable degree of accuracy. The model is assumed to be composed of structural parameters such as demand, supply and production elasticities, and unexplained disturbances or random shocks.

The models are <u>structural</u> and <u>predictive</u>. That is, emphasis is placed on estimating reliable coefficients of meaningful variables rather than on finding a set of variables that merely predict accurately. It is necessary to estimate these structural coefficients to appraise the implications of a change in one variable in the model. In the terminology of Tinbergen (111), some variables may be classified as potential policy <u>instruments</u>. The structural models provide the basis for evaluating the effectiveness and efficiency of alternative instruments for attaining policy <u>targets</u> such as lower farm output, reduced costs, etc.

Structural equations are estimated by statistical techniques using time series from secondary sources. The analysis is highly aggregative and is oriented to broad national problems and policies. A macro analysis (computation of macro parameters from macro variables) seems appropriate since: (a) aggregation of micro parameters is impractical in many instances, (b) the cost is low, and (c) the aggregate analysis provides a methodological background for subsequent micro analysis. Later, it may be desirable to supplement this study with analyses by geographic regions, alternative time periods, classes of farms and with additional models and techniques.

The setting for this study, including the economic and statistical models, aggregation procedures and data reliability, is established in Chapters 2, 3 and 4. Inputs are grouped into three principal categories: operating or working capital, durable or fixed capital, and labor. Chapters 5 and 6 contain estimates of demand and supply functions of aggregate operating inputs and six components including fertilizer, seed, etc. Investment in several categories of farm durables is analyzed in Chapters 7, 8 and 9. In Chapter 10, family and hired labor functions are estimated. Chapters 11 and 12 essentially are a summary and synthesis of quantities derived in earlier chapters. In Chapter 11, the output supply function for farm products is derived from direct estimates and from previously estimated input demand functions. Chapter 12 contains concluding remarks, including a summary of the influence of non-farm variables on the input structure of agriculture.

A Note on Goals and Welfare

In highly developed, specialized economies, the economic fortunes of individuals sometimes become exogenous or autonomous to their own actions. In a static or slowly changing competitive society, the price mechanism may be quite adequate to bring adjustments consistent with societal welfare, subject to the income distribution. There would be little need for economists in such a society.

Modern, imperfectly competitive, dynamic economies desire growth, as well as justice, stability and freedom. An economy characterized by rapid growth and technological gains may find the rewards unequally distributed among groups. These disadvantaged groups may feel that the price mechanism is not adequate to bring needed adjustments and increasingly turn toward the government for ameliorative action. If the gains from increased efficiency are large, as for U.S. agriculture, it is possible to compensate farmers and still have a higher real income in society. Whether society considers it desirable to compensate farmers depends on the unknown social welfare function. The relative weights placed by society on freedom, justice, stability and growth are unknown to the economist. But unless an infinite weight or price is placed on a goal such as freedom, the optimum choice from a set of alternatives cannot be made by society without some knowledge of how much freedom, for example, is forgone to gain additional income (security or growth). Almost any policy involves more than one goal of society. Farm incomes can be raised by stopping technological change in agriculture (loss of growth) or by strict output controls (loss of freedom). Perhaps freedom and growth might be preserved by a return to free markets, but farmers would argue that justice and security are sacrificed.

The world becomes more deterministic as logic and modern research methods are applied to situations of confusion, doubt and uncertainty. From the additional knowledge, it is possible to predict with varying degrees of precision how much of one goal is sacrificed to gain more of another. In this study, for example, the effect on farm income from various policy alternatives is examined. In Chapter 11, the loss in farm income associated with a return to free markets is estimated. Society must decide whether free markets (freedom to make individual decisions) or controls (security of farm income) or some combination of these means and ends is consistent with greatest welfare. Although we do not specify what action should be taken, we do assume that society is better able to maximize welfare with more knowledge of the alternatives. This study is predicated on the value judgment that more knowledge is superior to less knowledge.

CHAPTER 2: AN ECONOMIC MODEL OF THE STRUCTURE OF AGRICULTURE

The principle purpose in Chapter 2 is to synthesize the behavioral, institutional and technological forces determining income, output and efficiency in agriculture into a simplified economic model adaptable to empirical estimation. The procedure is to begin with concepts suggested by static economic theory of the firm and industry. Dynamic conditions of the real world introduce questions concerning the nature of causality, degree of interdependence among variables, time lags, and other fundamental concepts. These are discussed only to the extent considered relevant for the model. Throughout, resource markets are emphasized. Finally, the elements from economic theory, logic and introspection are combined into a general structural model of agriculture.

Some Considerations from the Theory of the Firm

The static theory of the firm is a useful starting point for construction of a structural model since: (a) under certain assumptions the agricultural industry is analogous to a firm and (b) the firm is a logical beginning point for analysis of the general equilibrium of production. We begin with the assumptions that the decision maker maximizes profits in an environment of known input-output and price ratios, instantaneous adjustments, divisibility of commodities (inputs or outputs) and unlimited capital. Furthermore, individual decisions are assumed to have no influence on price under these competitive conditions.

The production function of the firm is

(1) $$Y = f\ (X_1,\ X_2,\ \ldots\ X_n) = 0$$

where X_1, X_2, ... X_n are resources used in production of output Y. Let $f_i = \partial Y/\ \partial X_i$ be the partial derivative of the production function (marginal product) with respect to X_i. The competitive firm sells its product Y at a given price P_y and buys its resources X_1, X_2, ... X_n at given prices P_1, P_2, ... P_n, respectively. The expression for maximum profits π when X_1 and X_2 are variable, X_3, X_4, ... X_n fixed, is

(2) $$\pi = P_y\ f(X_1,\ X_2,\ X_3\ \ldots\ X_n) - (P_1X_1 + P_2X_2 + F)$$

where F is fixed cost. The first order condition for profit maximization is $d\pi = 0$, or

(3) $$\frac{d\,\pi}{d\ X_1} = P_yf_1 - P_1 = 0 \qquad \frac{d\pi}{d\ X_2} = P_yf_2 - P_2 = 0$$

or

(4) $$f_1 = P_1/P_y \qquad \text{and} \qquad f_2 = P_2/P_y.$$ [1]

Solving f_1 and f_2 simultaneously for X_1 and X_2, the derived demand functions for these inputs become

(5) $$X_1 = g_1\ (P_1/P_y,\ P_2/P_y\ \mid\ X_3,\ \ldots\ X_n)$$

and

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[1]For second order conditions of profit maximization, see Hicks (59, p. 320).

$$(6) \qquad X_2 = g_2\,(P_1/P_y,\ P_2/P_y \mid X_3,\ \ldots X_n).$$

With some modifications for dynamic conditions, equations 5 and 6 provide the foundation for the single equation demand functions estimated empirically in this study. Certain characteristics of static derived demand function for the competitive firm are either overlooked or are the subject of controversy. Two of these characteristics which we shall discuss are: (a) the use of price ratios and (b) the role of fixed resources in input demand.

The use of price ratios

From equations 5 and 6 it is apparent that the input demand quantity depends on the ratio of all variable factor prices to the price of the product. The use of price ratios, suggested by static theory, implies a symmetry in response of the demand quantity to product and factor prices. The demand function is homogeneous of degree zero. If all product and factor prices change by the same proportion, the demand quantity remains unchanged. The symmetry also has implications for elasticity estimates. We define elasticity of demand E_{cd} for input X with respect to output price P_y as

$$(7) \qquad E_{cd} = \frac{\partial X}{\partial P_y} \cdot \frac{P_y}{X}\ ,$$

and the elasticity with respect to the price of related inputs P_1 as

$$E_{d(i)} = \frac{\partial X}{\partial P_i} \cdot \frac{P_i}{X} \quad (8)$$

It can be demonstrated (Cf. 115) that

$$E_{cd} = - \sum E_{d(i)} \quad (9)$$

Equation 9 indicates that the elasticity of demand with respect to output is equal numerically but opposite in sign to the sum of the elasticities of X with respect to own-price and other input prices. Static theory indicates that the elasticity of demand for combines, for example, with respect to the price of grain is equal numerically to the sum of the elasticities with respect to the prices of combines, gasoline, tractors, trucks and other inputs related to combines. If the demand is a function only of output and own-price,

$$E_{cd} = - E_d \quad (10)$$

and the elasticity of fertilizer demand with respect to the price of crops or the price of fertilizer are equal (opposite signs, of course).

Static theory suggests the use of price ratios, dynamic economic theory raises doubts about the appropriateness of such forms. Farmers must make decisions of how much X to use on the basis of expected rather than actual product prices because of the length of the farm production period. The expected or normal price is a subjective estimate made by farmers on the basis of the permanent and transitory components of current and past prices. These components are of a different nature in output and input prices. It can be argued that the permanent component is a much greater proportion of input price than of output price. When production plans are made, considerable uncertainty may exist about output price due to the time lag in production. Planning the level of use, purchasing and applying inputs are nearly concurrent acts, hence, there need be little uncertainty about input prices. Also, the historic stability of input prices tends to create a large permanent component relative to the transitory component of input prices. The symmetric nature of price ratios implies that if output and input prices increase or decrease by the same proportion, the demand quantity remains unchanged. However, if farmers make decisions on the basis of the "permanent" component of price changes, a proportional increase in actual output and input prices could be expected to decrease the demand quantity since the permanent component of input prices is greater. For these reasons the use of price ratios in dynamic models does not appear justified in all cases.

Price ratios have certain advantages in statistical time series applications: (a) avoidance of errors from use of general price deflators (e.g. the wholesale price index), (b) reduction of multicollinearity, and (c) increased degrees of freedom. Although use of price ratios is not strictly correct from a logical standpoint, the advantages may justify the use of ratios if the errors are not large. The results of the Interstate Managerial Survey (15, 71) indicate that equations 5 and 6 may be appropriate with certain modifications. One modification is to account for the differential nature of resource flows under changing prices. That is, separate supply or demand functions may exist for price increases and for price decreases. The Interstate Managerial Survey further indicates, though inconclusively, that farmers respond more readily to input price changes than to output price changes. A higher percentage of farmers adjusted production when an input price changed than when an output price changed.

Studies by Heady and Yeh (57) and by Cromarty (26) support the hypothesis of a symmetric response to input and output price changes by farmers. In these studies, input and output prices were included as separate variables. Cromarty (26, p. 327) found the elasticity of farm machinery purchases with respect to own and output price was -1.0 and 0.7, respectively. Although not tested statistically, the difference probably is not significantly different from zero. Heady and Yeh (57, p. 334) found the elasticity of fertilizer purchases with respect to fertilizer price to be -0.49 in one equation, 1.71 in a second equation. The elasticity of fertilizer purchases with respect to crop price was estimated to be 0.47 -- similar to the first estimate but considerably less than the second. Clearly, there is some support for the hypothesis that the price ratio is the decision variable used by farmers. However, other studies showing unequal elasticities with respect to output and input prices are not hard to find.

To summarize, if the sacrifice in higher intercorrelations, loss of degrees of freedom and errors from general deflators is considered less than forcing a symmetric response to input and output prices, the separate input and output price variables should be included in regression estimates. Empirical results thus far provide insufficient evidence to reject the hypothesis of symmetric price response. The use of price ratios is likely to continue in empirical applications.

Related inputs in the static demand function

Quantitative demand studies for a given input often have ignored other inputs. It is well to explore the contribution of static economic theory to the role of other inputs in demand functions. Unless a resource X_j is independent of X_i in production, it must be included in the static demand function for X_i. In a static framework, the price of X_j is included in the demand function if the resource is variable (Cf. equations 5 and 6). However, if X_i and X_j are independent, the price of X_j drops out, and the "long run" demand function for X_i (X_i and X_j variable) is the same as the "short run" demand function (X_i variable). Thus, the exact empirical counterpart of the static demand equation must include prices of all related (non-independent) variable inputs.

If X_j is <u>fixed</u> but related in production to X_i the <u>quantity</u> is included in the static demand function for X_i. The level of X_j merely may shift the <u>level</u> of the demand curve for X_i, leaving the slope unchanged. Many empirical studies either ignore the influence of fixed factors or assume a neutral shift. A demand function with the quantity X_i a linear function of the quantity of the fixed factor X_j and of other variables in original values assumes a neutral shift. Other empirical functions of the same type but in logarithms assume compensating shifts in the level and slope of the demand curve, leaving the elasticity constant at all fixed factor levels. The signs and magnitudes of the parameters of fixed factors depends on the extent of substitutibility or complementarity among factors and the stage of production.

The static supply function

The static supply function for the profit maximizing firm is derived by substituting the static demand equations 5 and 6 into the production function (equation 1). The implicit supply function

$$Y = h\,(P_1/P_y,\ P_2/P_y \mid X_3,\ \ldots\ X_n) \tag{11}$$

depicts the supply quantity Y as a function of the factor-product price ratios and the level of fixed factors. If the firm sold products in addition to Y, the supply function would be a function of all product prices and all variable input prices in the form of ratios. Analogously to equation 9, it can be shown that the supply elasticity with respect to output price is equal numerically but opposite in sign to the sum of elasticities with respect to input prices. Thus, if the elasticity of agricultural output with respect to prices received by farmers is low, then the output elasticity with respect to input prices is also low. It follows that in such circumstances a given (proportional) tax or subsidy on all input prices or on output price would have the same effect on output.

Relationships among supply, demand and production elasticities

In this study the main concern is with demand rather than with supply functions. A major objective, however, is to explain supply on the basis of the demand functions. Since output is a function of the magnitude of inputs and the technology of the transformation function, one might anticipate an exact theoretic relation between input demand, product supply and the production function. A useful theoretic relation may be expressed as follows:

The elasticity of supply or output Y with respect to output price P_y is defined as

(12) $$E_s = \frac{dY}{dP_y} \cdot \frac{P_y}{Y} \; ;$$

the elasticity of production for resource X_i as

(13) $$E_{p(i)} = \frac{\partial Y}{\partial X_i} \cdot \frac{X_i}{Y} \; ,$$

and the elasticity of derived demand for resource X_i with respect to output price P_y is

(14) $$E_{cd(i)} = \frac{dX_i}{dP_y} \cdot \frac{P_y}{X_i} \; .$$

It has been demonstrated by Tweeten and Heady (115) that

(15) $$E_s = \Sigma E_{p(i)} \, E_{cd(i)} \; .$$

It is therefore possible to express output supply elasticity from knowledge of the production and factor demand functions. The equation can be made dynamic and used to express elasticity over various periods of time by placing time subscripts on E_s and E_{cd}. In a later chapter, this procedure is used to estimate the aggregate supply elasticity.

Griliches (46) used an equivalent procedure to derive an estimate of aggregate supply for agriculture. Instead of production elasticity E_p, he used factor shares. The factor share F_i for the resource X_i is

(16) $$F_i = \frac{X_i P_i}{Y \, P_y} \; .$$

In equilibrium,

(17) $$P_i = \frac{\partial Y}{\partial X_i} P_y \; .$$

Substituting the right side (marginal value product) of

$$(18) \qquad F_i = \frac{X_i}{Y\ P_y} \left(\frac{\partial Y}{\partial X_i} P_y \right) = E_{p(i)} \ .$$

It is apparent that the supply elasticity may also be expressed as the sum of the factor shares times the elasticity of demand with respect to product price. The use of factor shares may not be justified since the exact equilibrium condition indicated by equation 17 does not hold.

Industry Supply and Demand

Economic theory of the competitive industry introduces additional concepts which must be considered in any empirical estimation of the resource structure. For a small segment of agriculture, the price of non-farm inputs may be assumed as given or exogenous. That is, the actions of a small group of farmers has little influence on the prices of resources supplied by the non-farm sector. The action of one farmer or a small group of farmers also has little influence on the prices they receive for farm products. Thus, prices may be assumed exogenous, i.e. determined by forces outside the system being examined. Only farm output and resource inputs are endogenous (determined within the system) and the quantity of any input may be estimated as a monocausal function of prices and fixed factor levels as in demand equation 5. Also agricultural supply or output for a small group of farmers may be considered a simple function of prices as in equation 11.

The most general model of industry supply and demand is the Walrasian general equilibrium system. According to the Walrasian system, prices and quantities of commodities are determined interdependently by a system of demand and supply equations. The complete Walrasian system includes demand and supply functions in the entire economy. Even if the simultaneous system is considered pertinent, empirical models necessarily must abstract from the more remote markets in the entire economy and must emphasize the markets for agricultural inputs and outputs.

The type of economic (and statistical) model chosen to represent the market structure of agriculture depends strongly on the underlying causal framework. A direct relationship exists between the nature of causality specified in the economic model and the type of statistical model chosen to estimate the parameters. For present purposes, we avoid an extended discussion of the ontological aspects of causality. Rather we consider only the immediate, pragmatic aspects of causality and emphasize those considerations necessary in constructing economic models.

The static equilibrium models of Walras, Marshall and others stress the interdependence of supply and demand in determining equilibrium price and quantity. The early econometric analysis of supply and demand from time series data, however, assumed a monocausal relationship. That is, price (or quantity) was chosen as the dependent (effect) variable, and was considered a function of the quantity (or price) and other independent (causal) variables. Econometricians such as H. Schultz (104, pp. 72-114) and Working (136) were uncomfortable with this simple cause-effect relationship. They realized that only under certain conditions could the structural demand or supply function be identified using the single equation, least squares statistical model. This led to the development of statistical procedures which allowed for the simultaneous determination of price and quantity by supply and demand, and thus for the identification of structural economic relationships in an interdependent system (53, 63, 83).

The new statistical techniques satisfied the basic premise of interdependence derived from static economic theory and economists hailed the new methods as a greatly improved tool for analyzing supply and demand. Possibly due to the computational burden and other shortcomings of the newly developed statistical techniques, economists began to reexamine the adequacy of least squares single equations (8, 9, 35). The nature of the causal structure underlying economic variables in the real world was the fundamental point in the reexamination. In particular, the Stockholm school questioned the basic premise of simultaneity in dynamic economics. The fact that decisions take time led them to conclude that economic decisions are not made simultaneously. Instead, they conceive of the recursive model as the most fundamental at an abstract level of economic theory. The recursive model is composed of a sequence of causal relationships. The values of economic variables during a given period are determined by equations in terms of values already calculated, including the initial values of the system.

Much intuitive appeal lies in the disequilibrium nature of the recursive system. For example, in agriculture it seems logical that the current supply quantity often is determined by past price and the current year price is a function of the predetermined current quantity. Commodity cycles, conceptualized in this type of recursive system -- the cobweb model -- give strong support for the disequilibrium model in agriculture. Simultaneous equations that include only current price and quantity, are dynamic <u>equilibrium</u> models, and may not be appropriate where production is predetermined and cycles are apparent. The conclusion is that if the economic model is sufficiently detailed and adequately specified, and if the time period is sufficiently short, the recursive model may be appropriate.

Surprisingly, the real basis for interdependent models does not seem to arise from the static economic equilibrium models of Walras, <u>et al</u>., but from the exigencies of empirical data. One example is aggregation of data over time. Suppose that A determines B, B determines C, and C determines D through time. If A is aggregated with C, and B with D, then a joint "causal" relationship exists between the aggregate A C and B D.

The Market for Agricultural Inputs

The interdependence of markets for agricultural <u>products</u> has been emphasized in the literature. The need to specify interdependence in markets for agricultural <u>inputs</u> largely has been ignored. Surprisingly, little is known of the nature of the supply function for agricultural inputs. Empirical studies of agricultural output traditionally have ignored supply functions. Yet, it can be shown that the output supply function can not be realistically expressed without knowledge of input supply.

Consider the example of the supply equation 19 for a resource X_1

$$X_1 = a\ P_1^b \tag{19}$$

where P_1 is the input price and b is the input supply elasticity. Assume the production function is a power function

$$Y = c\ X_1^d \tag{20}$$

where Y is farm output and d is the elasticity of production. The output supply function derived from equations 19 and 20 is

$$Y = K\ P_y^{\frac{b\ d}{1+b-bd}} \tag{21}$$

where Y is the supply quantity, P_y is product price and

$b\,d/1+b-bd$ is the product supply elasticity E_s.[2] As the input supply elasticity b approaches zero, E_s also approaches zero. As the input supply elasticity b approaches infinity, the product supply elasticity approaches $d/1-d$. For a given production elasticity d, the output supply elasticity is an increasing function of the input supply elasticity. <u>Ceteris paribus</u>, the greater the value of b, the greater the value of E_s. Two interesting observations are apparent from equation 21. With constant returns to scale (d=1), then $E_s = b$. That is, the input and output supply elasticities are equal. If the supply of inputs is perfectly elastic, the output supply elasticity $d/1-d$ is exactly the same as would be found

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[2]Solving for P_1 in equation 19 and X_1 in equation 20, and substituting these into the expression

(a) $$T\,C = P_1X_1 + F$$

the total cost T C becomes a function of variable cost $P_1X_1 = f\,(Y)$ and fixed cost F. The derivative of T C with respect to Y may then be equated to product price P_y from the assumption of profit maximization. Solving for Y in terms of P_y, the supply function is

(b) $$Y = \left[a^{\frac{1}{b}}\, c^{\frac{1+b}{bd}}\, \frac{bd}{1+b}\, P_y \right]^{\frac{bd}{1+b-bd}} .$$

Letting

(c) $$K = \left[a^{\frac{1}{b}}\, c^{\frac{1+b}{bd}}\, \frac{bd}{1+b} \right]^{\frac{bd}{1-b-bd}}$$

(b) becomes

(d) $$Y = K\, P_y^{\frac{bd}{1+b-bd}} .$$

by omitting the input supply equation 19. It follows that past empirical investigations of product supply and factor demand essentially have assumed the input supply curve is horizontal.

A hypothetical three equation model showing interdependence

A simple economic model emphasizing the resource markets in agriculture will clarify the implications of a model stressing interdependence in agricultural resource markets. Assume that the supply of agricultural products Y and input price P_1 are determined jointly in association with the product price P_y

(22) $$Y, P_1 ; P_y .$$

Variables to the left of the semicolon are endogenous, those to the right are predetermined. The farm derived demand function for input X_1 is

(23) $$X_1, P_1 ; P_y$$

and the input supply function is

(24) $$X_1, P_1 ; P_{NL}$$

where P_{NL} is the wage of non-farm labor. The simple model indicates that neither price P_1 nor quantity X_1 may be selected as the only dependent (endogenous) variable in a single equation. Whether this particular model is realistic for agriculture depends on: (a) the extent to which current input prices are important in determining farm output, and

(b) if current input prices are important, to what extent they are endogenous. Many input prices are specified for the calendar year rather than for the production year. Hence, prices of the current year are known when many production plans are made. With some crops such as corn, decisions based on favorable current prices to side dress fertilizer can be made well after the start of the production period. Similar types of decisions can be made for livestock -- whether to feed to heavier weights on the basis of favorable feed grain and protein prices. A study by Tweeten and Heady (115) also reveals the potential response of output (and inputs) to a change in current input prices is small but greater than zero. There is little doubt that current prices exert some influence on the input demand quantity, and hence, influence farm output.

Despite the importance of current prices of inputs in the supply function, the interdependent model need not be specified if the input supply is highly elastic. Input price may then be considered exogenous and simultaneous model resolves to a recursive system of single equations.[3] Empirical

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[3]There may be more than one endogenous variable in an equation in a recursive model, but the matrix of coefficients of these endogenous variables must be triangular. In essence, the recursive system is interdependent but not simultaneous. The above three equation model resolves to a recursive system if the current input supply price becomes predetermined, i.e. determined by exogenous and lagged endogenous variables. Let the input supply equation 24 be (Continued on next page)

knowledge of input supply elasticity is meager. Introspection, logic and economic theory suggest some characteristics of input supply which can be of value in specifying the economic models. Three categories of agricultural inputs, non-farm produced capital, farm produced capital and labor inputs, are discussed with emphasis on the magnitude of supply response and the degree of current interaction between supply and demand.

Non-farm produced capital

A study of the nature of supply of non-farm produced capital is of interest because of the growing relative importance of these resources in the agricultural input structure and also because of the existing lack of knowledge in the area. Several considerations suggest the hypothesis that the elasticity is high. These considerations may be summarized

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(Footnote continued from previous page)

(a) $P_1' \; ; \; X_1', \; P_{NL}$ (Input supply)

where P_1', the current input price, is predetermined by past year input sales X_1' and non-farm wages. The output supply equation 22 and input demand equation 23 may be written

(b) $Y \; ; \; P_1', \; P_y$ (Product supply)

and

(c) $X_1 \; ; \; P_1', \; P_y.$ (Input demand)

The predicted value of P_1' from (a) may be used to estimate (b) and (c) to insure that the current residual is independent of input price. It is apparent that each equation may then be estimated by ordinary least squares.

into the categories: (a) the historic input price-quantity relationships, (b) empirical studies of the cost structure of non-agricultural industries, (c) the degree of competition among input supplying firms, (d) the goals of these industries, and (e) the relative importance of agricultural purchases in the sales of non-farm firms.

The historic short run stability of input prices gives some evidence that input supply is highly elastic. The fact that shifts in input demand due to weather and product price changes have not resulted in appreciable input price changes implies a high input supply elasticity, at least in the short run.

Empirical studies of major non-farm firms reveal near constant or slowly rising average and marginal cost curves. Because the short run industry supply curve is the horizontal summation of firm marginal cost curves, industry supply is likely to be highly elastic. Further, most economists agree that competition among non-farm suppliers of agricultural inputs is less than perfect. Hence, the actions of suppliers are interdependent. In such instances of monopolistic competition and oligopoly, emphasis is placed on non-price competition. The result tends to be a stickiness of prices at various quantity levels due to fear of recrimination by other suppliers.

Some economists (7) indicate that goals other than maximum total profit are important in business decisions. These include securing public good will, earning a stable return on investment, a fixed margin on costs of production and other goals. Despite an increase in marginal cost at higher output, a firm may not increase price for fear of losing public goodwill. When agricultural demand for an input increases, a supplier concerned with earning a stable return on investment may find it possible to maintain this return by maintaining or possibly by decreasing price. The latter case could give rise to a negative (but high in absolute terms) supply elasticity. If the manufacturer desires a cost-plus markup, the tendency could be to increase the supply elasticity. For example, a fixed margin above the marginal cost results in a "supply curve" more elastic than the marginal cost curve.

Finally, the importance of agricultural purchases in the total sales of the input supplier may influence the degree of supply elasticity. If a manufacturer sells only a small portion of his output to agriculture, an increase in agricultural demand may allow him to supply the increased quantity with little impact on the firm's cost structure. The change in input demand may be almost unnoticed, and the result is likely to be a highly elastic input supply. Since many firms supplying inputs to agriculture also supply inputs to other economic sectors, the declining nature of agriculture relative to other industries tends to increase supply elasticity. On the other hand, non-farm inputs are substituting for farm produced inputs. Use of non-farm inputs is increasing relative to farm output, and is rising in absolute amounts. This tendency, along with increased specialization of manufacturers in producing farm inputs tends to reduce supply elasticity.

It seems reasonable to conclude that the supply of non-farm inputs is highly elastic. A distinction might be made between supply at the industry and farm level. Assuming a constant or decreasing margin at higher prices, the industry supply is less elastic than supply at the farm level.

Labor inputs

The magnitude of labor supply elasticity primarily is a function of the relationship of farm to non-farm wages and the degree of unemployment in the non-farm sector. Recent historical experience does not provide any insight into the nature of labor supply elasticity in periods of expansion in agriculture. The magnitude of the labor supply elasticity in periods of a relative declining agricultural earnings is of more interest. Due to education, knowledge of off-farm opportunities and improved transportation, the potential for movement of labor out of agriculture is relatively large in periods of high national employment. If relative prices and incomes in agriculture are low, a reasonable hypothesis is that supply elasticity is somewhat greater than zero during periods of high employment and zero or negative during periods of high unemployment. It probably is safe to consider national unemployment exogenous, that is, unemployment in the entire economy probably is not influenced to a significant extent by farm labor movement. Current supply conditions for labor may have a substantial influence on the farm wage rate and the number of workers in agriculture. The exact extent to which current labor input and prices are determined jointly by supply and demand is difficult to judge, but the case for interdependence appears stronger than for any other major farm resource.

Farm produced capital

The magnitude of the supply elasticity of farm produced inputs such as feed, seed and livestock is a function of the agricultural production process. The supply elasticity of resources such as livestock which require a long production period is low. The magnitude of supply elasticity for inputs which can be produced in one year is higher, but perhaps is somewhat less than the supply elasticity of inputs produced off farms. Farm produced resources such as feed and livestock inventories are intermediate. The fundamental resources needed to produce these are non-farm capital, labor and land. Non-farm capital and labor are discussed earlier. The supply of land is highly inelastic and may be omitted except in a long run model. In the general model presented in the following pages, we attempt to abstract from the problem of intermediate resources and emphasize rather the more fundamental resources.

The Economic Model

In this section we present an aggregate economic model of agriculture, stressing resource markets. The previous discussion provides no clear mandate that either single or simultaneous equations is the correct model of agriculture. Rather, the discussion indicates that a rationale exists for either type, depending on the nature of the data and market being studied. The eclectic problems of model formation are not solved by introspection and logic alone. Previous considerations emphasize the need for empirical evidence of the degree of interdependence in resource markets. For these reasons, both the single and simultaneous models are employed throughout the later empirical sections. The model presented in this section emphasizes the interdependence of the agricultural structure. Simplified single equation models are presented when pertinent in subsequent chapters. In general, the specification of the single and simultaneous models are similar, except that only one variable is considered endogenous in the single equations.

A fundamental interdependent model would include supply and demand equations for all related commodities at all market levels. It also would include every explanatory hypothesis that conceivably might influence the market. The following is a compromise between the highly detailed model and one which statistically is manageable. The structure is considered only at the farm level, interfarm markets and intermediate farm resources largely are omitted, and only the hypotheses (variables) considered most relevant in the structure are included.

The model is short run. The real estate market is not expected to influence the economic structure in the short run, and is excluded. Farm size and the number of farms is hypothesized to influence the structure in the short run, however, due to the scale effect on production and input purchases. Because the acreage of farm land is nearly fixed, only a single variable, farm numbers, is sufficient to measure both the size and numbers components. Some additional simplification is necessary in later empirical chapters because of intercorrelations among variables, and because of data limitations.

The variables

The following variables are included in the model. The first ten variables are endogenous -- determined within the model. The remaining variables are predetermined, i.e., either lagged values of endogenous variables or exogenous variables considered to be determined outside the current agricultural structure. To facilitate interpretation, the variables are assigned alphabetic notations with identifying symbolisms to relate the variable and the notation. The variables are defined as follows:

Q_{Ot} The quantity of cash operating expendables purchased by farmers in the current year.

P_{Ot} The current price of cash operating expendables.

Q_{Mt} The quantity of all farm machinery purchased by farmers in the current year.

P_{Mt} The current price of all farm machinery.

Q_{HLt} The employment of hired labor by farmers in the current year.

P_{HLt} The current composite wage rate for hired farm labor.

N_t The number of farms in the current year.

Q_{St} The aggregate quantity of products supplied by farmers for consumption, for non-farm and government storage, and for export in the current year. From another standpoint, the variable is current output less changes in farm inventories.

Q_{Dt} The quantity of farm products domestically consumed in the current year.

P_{Rt} Prices received by farmers during the current year for crops and livestock.

In addition to the above endogenous variables, the following predetermined variables are included:

S_{pt} The stock of productive farm assets at the beginning of the current year.

W_t An index of the effect of weather on farm output in the current year.

G_t An index of the type of government programs on major crops and livestock in the current year.

E_{t-1} The ratio of farmers' owned assets to indebtedness in the past year.

Y_{Ft-1} Net income of farm operators the past year.

r_{t-1} Interest rate on short-term farm loans the past year.

P_{Pt-1} Prices paid by farmers for items used in production, interest, taxes and wage rates in the past year.

M_{t-1} Farm output per man hour during the past year.

P_{NLt} The wage rate of labor employed in manufacturing in the current year (non-farm wage rate).

U_t The proportion unemployed of non-farm labor in the current year.

P_{ISt} Wholesale prices of iron and steel in the current year.

Y_{Dt} Disposable personal income for the U.S. in the current year.

Q_{ESt} The net quantity of farm product exports and additions to non-farm stocks in the current year.

T A variable reflecting the structural impact of factors which change uniformly through time. The time variable T is the last two digits of the current year.

C_t A variable reflecting the once-for-all shift in structure during the World War II period. The variable is zero during the prewar period; 100 during the postwar period.

The equations

The following overidentified structural model is presented in terms of the above variables. Since the logic of the model has been discussed throughout the chapter, only a few comments are included with the equations. The commas may be read "and" and the semicolons as "are jointly determined, and appear in relationship with". Variables to the left of the semicolon are endogenous; those to the right predetermined.

Purchases of current operating expendables

(Demand)

(25) Q_{Ot}, P_{Ot}, P_{Mt}, P_{HLt}, P_{Rt}, N_t ; P_{Ot-1}, P_{Rt-1}, S_{pt}, W_t, G_t, T

(Supply)

(26) P_{Ot}, Q_{Ot} ; P_{NLt}, C_t

Purchases of farm machinery

(Demand)

(27) Q_{Mt}, P_{Ot}, P_{Mt}, P_{HLt}, P_{Rt}, N_t ; P_{Mt}, P_{Rt-1}, E_{t-1}, Y_{Ft-1}, r_{t-1}, T

(Supply)

(28) P_{Mt}, Q_{Mt} ; P_{NLt}, P_{ISt}, C_t

Hired farm labor

(Demand)

(29) Q_{HL}, P_{Ot}, P_{Mt}, P_{HLt}, N_t ; P_{HLt-1}, P_{Rt-1}, S_{pt}, T

(Supply)

(30) P_{HLt}, Q_{HLt} ; P_{NLt}, $P_{NL}\,(1 - 5U)_{t-1}$, C_t

Farm size

(31) N_t, P_{Ot}, P_{Mt}, P_{HLt}, P_{Rt} ; M_{t-1}, $P_{NL}\,(1 - 5U)_{t-1}$

Market for farm products

(Supply)

(32) Q_{St}, P_{Ot}, P_{HLt}, P_{Rt} ; P_{Pt-1}, P_{Rt-1}, S_{pt}, T

(Demand)

(33) P_{Rt}, Q_{Dt} ; Y_{Dt}, C_t

Identity

$$Q_{St} = Q_{Dt} + Q_{ESt}$$

The supply quantity Q_S is made endogenous because of possibilities for changing the amount of farm inventories in the current year and because of the consequent interaction with P_R. With knowledge of the parameters relating the variables, these ten equations in ten unknowns permit prediction of the endogenous variables (left of semicolon) from known values of the predetermined variables (right of semicolon). The ten endogenous variables are the prices and quantities of farm output and inputs, and farm numbers. From these variables, other quantities of interest may be found such as expenses, gross income, net income. These concepts may be computed in total for agriculture, per unit of labor or per farm. In addition, several measures of resource efficiency are available from quantities determined by the model. Examples of concepts that may be derived from the model are as follows:

Gross income

(34) $Y_{Gt} = P_{Rt} Q_{St}$

Current operating expenses, excluding labor

(35) $E_{Ot} = P_{Ot} Q_{Ot}$

Operating expenses, including labor

(36) $E_{OLt} = E_{Ot} + P_{HLt} Q_{HLt}$

Net income:

Net of operating expense

(37) $Y_{Gt} - E_{Ot}$

Net of operating and hired labor expense

(38) $Y_{Gt} - E_{OLt}$

Income or expense per farm

Gross income per farm

(39) Y_{Gt}/N_t

(Any of the other expense or income concepts may be expressed on a per farm basis by dividing by N_t.)

In an alternative model, total employment (hired and family) of labor in agriculture Q_{TLt} is substituted for Q_{HLt}. The assumption is that the wage of hired labor is a relevant decision variable for family labor as well as for hired labor. With Q_{TLt} as an endogenous variable, the model allows prediction of gross and net farm income on a per unit of labor basis. Simply divide income or expenses by Q_{TLt}.

Several measures of efficiency may be found from the predicted quantities in the model. Examples are output per unit of labor, operating items or machinery. If the supply quantity Q_S is annual output, the output per unit of labor or operating items may be computed as equation 40 or 41 respectively.

(40) Q_{St}/Q_{TLt} (41) Q_{St}/Q_{Ot}

The output per unit of durable asset <u>services</u> cannot be computed directly. For example, only annual purchases of machinery Q_{Mt} are given by the model. The annual input of machinery services Q'_{Mt} can be computed from known values of beginning year machinery stock S_{Mt}, the interest rate r and depreciation rate d. The end of year (January 1, t+1) stocks are then

(42) $$S_{t+1} = Q_{Mt} + (1 - d)\, S_{Mt} .$$

The annual input Q'_{Mt} of machinery is then computed as the depreciation plus interest on average investment.

(43) $$Q'_{Mt} = d\, S_{Mt} + \frac{r}{2}\,(S_{Mt+1} + S_{Mt}) .$$

The output per unit of machinery is

(44) $$Q_{St}/Q'_{Mt} .$$

The model establishes a useful framework for ascertaining the influence of changes in non-farm variables such as the wage rate P_{NL}, disposable income Y_D, unemployment rate U and government purchases of farm commodities Q_{ES} on farm income, expenses and efficiency. It is well to point out that the economic model is discussed in terms of potential uses. What, in fact, can be determined by the empirical model also is a function of the statistical model and data.

CHAPTER 3: THE STATISTICAL MODEL

To derive an empirical model of the structure, it is necessary not only to specify the economic model, but also to select a satisfactory procedure for estimating the numerical values of parameters in the model. In this study, the parameters are estimated by econometric techniques from times series. The basic assumption is that the agricultural structure is the realization of a stochastic process through time. Variables such as prices and quantities are determined by supply and demand functions linear in the parameters (e.g. supply and demand coefficients or elasticites) and subject to random shocks or disturbances. Given these basic conditions, the parameters can be estimated by several statistical techniques such as least squares and limited information, two stage least squares, etc. To ascertain the appropriateness of these techniques, it is necessary to consider the criteria of a "good" estimator. The procedure in Chapter 3 is to examine: (a) the properties of a desirable estimator, (b) the conditions for these properties to hold, (c) how well the data and relationships in our economic model conform to these conditions, and (d) what precautions and procedures in handling data are available to insure reasonable adherence to the underlying assumptions of the statistical model. Throughout the chapter, particular emphasis is placed on the least squares estimators.

Desirable Properties of Estimators

The "goodness" of an estimator H' may be evaluated in terms of the following criteria (2, pp. 91-95): (a) Unbiasedness. An estimator is unbiased if its average value in the long run is equal to the population parameter H. That is, the expected value of the parameter estimate is equal to the parameter. (b) Consistency. An estimator H' is a consistent estimator of the population parameter H if H' converges stochastically to H as sample size becomes large. The absolute difference between H' and H becomes arbitrarily small as sample size increases. (c) Efficiency. An efficient estimator possesses minimum variance. An estimator is efficient if its variance is less than the variance of alternative estimators. (d) Sufficiency. A sufficient estimator exhausts all relevant information in the sample. Any other estimator may provide information about H', but necessarily must provide less information about the population parameter H.

In addition to these statistical criteria, the practical consideration of the amount of research resources required to compute the estimator also is important.

Assumptions Necessary to Obtain Desirable Properties of Estimators

Maximum likelihood estimators most nearly fulfill the desirable properties of statistical estimates. These estimators are sometimes costly to compute, however, and estimators such as ordinary least squares, more manageable in applied areas, are often used. Under certain assumptions, least squares possess the desirable properties of maximum likelihood estimators -- unbiasedness, consistency and efficiency. Since least squares procedures are used extensively throughout this study, it is well to review the assumptions necessary for these estimates to possess optimum statistical properties. The least squares statistical model is of the form

(1) $Y_t = B_{0t} + B_1X_{1t} + B_2X_{2t} + \ldots + B_nX_{nt} + e_t \quad (t=1,2,\ldots m)$

where Y and X_i are the dependent and independent variables, respectively. The B_i are the parameters of the model and e is the error. The assumptions of the model are:

(a) The parameters B_i are constants and enter the model linearly;

(b) The independent variables X_{it} are fixed (non-stochastic) and measured without error;

(c) The expected value of the error e is zero, i.e. $E(e)=0$;

(d) The covariance between the error e and the independent variables X_i is zero, i.e. $\sigma_{eX_i} = 0$ for all i;

(e) The error e is not autocorrelated, i.e. $\sigma_{e_t e_{t-i}} = 0$ for $i \neq 0$;

(f) The variance of the error is homogeneous over time, i.e. $E(e_t^2) = \sigma^2$ for $t = 1, 2, \ldots m$;

(g) The error e is normally distributed;

(h) The matrix of explanatory variables X_1 is not singular.

The least squares algorithm is to choose estimators b_1 for B_1 which minimize the squared deviations of the dependent variable from a linear combination of the independent variables. If the above eight conditions are met, least squares estimators possess the desirable statistical properties listed earlier. In addition least squares possess the practical advantage of computational convenience.

Implications of the Discrepancy between the Optimum Statistical Setting and Existing Conditions

The estimation of economic relationships from time series takes place in a setting quite unlike that outlined in the above eight assumptions. It is well that each one of these statistical assumptions be examined to determine: (a) to what extent they are met in empirical, time series analysis, (b) what influence deviations from the assumptions have on the desirable properties of estimators and (c) modifications of models and alternative algorithms permitting feasible estimates when conditions are not optimum.

Accommodating a dynamic structure

Perhaps the most notable characteristic of American agriculture is its changing structure. Although highly desirable from a physical and economic efficiency standpoint, the changing structure imposes statistical estimation problems due to failure to meet assumption (a) above. Changing structural parameters arising from droughts, wars, depressions, inflations or technological change may bias the statistical estimates. Certain precautions are advisable to avoid biased estimates due to a changing structure: (a) select data for a short time period when the structure was relatively homogeneous, and (b) omit unusual periods when a different structure was imposed by wars for example. A serious conflict arises in choosing a time period since large samples containing wide variation in the independent variables (due to wars and depressions perhaps) provide the most precise "significant" parameter estimates. The standard error of the coefficient of a variable is inversely related to the variation in the variable. Thus, the researcher is forced to compromise between a long time series to obtain precise estimates and a short homogeneous series to avoid statistical bias. These considerations prompted the use of annual data from 1926 to 1959, omitting the war years 1942 to 1945, to estimate most of the functions in this study. Structural estimates from shorter periods lack precision (small sample size and few degrees of freedom). Estimates from longer periods contain bias because of changes in structure and errors in data from earlier years.

Linear functions used in times series analysis are highly simplified models for expressing the complex technological, behavioral and institutional factors which determine supply and demand functions. Theoretically, even the most complex non-linear mathematical function can be approximated by a series of short, linear segments. By analogy, although the structure of agriculture may be complex indeed, the times series available for the narrow confines of recent historical experience provides only a segment of this structure. Perhaps this segment reasonably may be expressed by simple linear models. Several techniques are used in this study to accommodate a modified structure and allow use of data over longer periods. The most common technique, of course, is to include a time variable.[1] Time is a proxy variable for technology,

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[1]How time should be coded in a logarithm equation is debatable. Assuming the dependent variable is transformed into logarithms, inclusion of time as: (a) a simple untransformed linear index T results in an exponential function in T and (b) the logarithm of T results in a power function in T. The advantage of the power function (b) is that it allows the dependent variable (demand or supply) to increase at an increasing rate. Foote (33, pp. 40-42) argues that the typical time trend is one that increases at a decreasing rate, therefore, the power function (b) is appropriate. There are also advantages in using the untransformed index (a) of time. The results of (b) are not invariant to the origin of T. That is, whether T is coded as 1.00, 2.00, ... n or as 100, 200, ... 100n may result in a considerable (continued on next page)

improved knowledge and other variables that shift demand or supply uniformly through time. Inclusion of dummy variables often raises the R^2 appreciably, and leads to statements that we have "explained" the variation in the dependent variable. More appropriately, the increase in R^2 is a measure of our ignorance because it is not possible to impute the separate influence reflected by the coefficient of time to the underlying forces. The actual, basic variables should be included when possible. If the basic variables are unavailable, time must be included as a proxy variable to reduce the autocorrelation in the residuals.

Time included as a separate independent variable, indicates a shift in the position of a demand or supply curve over time. In some instances, the <u>slope</u> (or elasticity) of the curve may be a linear function of time. Inclusion of an interaction term of price with time allows the slope or elasticity to change. To allow for a single valued shift in the function during an abnormal period, a separate variable may be included with values of one during the abnormal period, zeros otherwise. If the abnormal period is one year, this

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(Footnote continued from previous page) difference in magnitudes of the standard errors, coefficients and R^2. But if T is coded as in (a) above, it makes no difference what origin is used. A further convenience of the exponential form (a) is the ease of finding the percentage shift in the dependent variable attributed to T. If the coefficient of T is c, the constant percentage shift in the dependent variable (or demand, supply or production curve) is found simply as: 100 (antilog c - 1).

method would be equivalent to leaving out the data for that year. The difficulty with the approach is that the change during an abnormal period generally is not single valued, but rather is of different magnitude each year. The abnormal period may leave a single permanent shift in the demand and supply curves. A single permanent shift in functions during the World War II years, for example, may be recognized by leaving out data for the war years and including a variable with values of zero during the prewar period; values of one during the postwar period. Changing response to price in various periods are allowed by including separate price variables for each structural period, with values of zero outside the period. Techniques as those above are used extensively in the empirical sections of this study to satisfy assumption (a) of the least squares model.

Errors in independent variables

If assumption (b) of the statistical model is not fulfilled, the least squares estimates are likely to be biased. The effect of errors in the explanatory variables on the parameter estimates may be illustrated by a simple example (35, pp. 31, 32; 109, pp. 69, 70). In a model of the form

(2) $$Y = B_0 + B_1X + e$$

we estimate B_1 by least squares as

(3) $$b_1 = \frac{\Sigma xy}{\Sigma x^2} .$$

Suppose that the observed variable x is composed of a systematic part X and an error term u, or

(4) $$x = X + u \ .$$

The observed y is also of the form

(5) $$y = Y + e \ .$$

The least squares estimate b_1 is therefore

(6) $$b_1 = \frac{\Sigma(Y+e)\ (X+u)}{\Sigma(X+u)^2} + \frac{\Sigma XY + \Sigma uY + \Sigma eX + \Sigma eu}{\Sigma X^2 + 2\Sigma uX + \Sigma u^2} \ .$$

By statistical assumption (d), the expected value of ΣeX equals zero (equation 7). Further, assume the errors in X and Y are independent (equation 8).

(7) $$E\ (\Sigma eX) = 0$$ (8) $$E\ (\Sigma eu) = 0 \ .$$

The expected value of b_1 from equation 6 is therefore

(9) $$E\ (b_1) = \frac{B_1\ (\Sigma X^2 + E\,\Sigma uX)}{E\,\Sigma u^2 + E\,\Sigma uX + (\Sigma X^2 + E\,\Sigma uX)} \ .$$

If b_1 is to be unbiased, i.e. $E\ (b_1) = B_1$, then it is apparent from equation 9 that the following must hold.

(10) $$E\,\Sigma u^2 + E\,\Sigma uX = 0.$$

This is an unlikely situation, however. If we further assume the error in x is uncorrelated with the systematic component of x, then

(11) $$E\,\Sigma uX = 0$$

and equation 9 reduces to

(12) $$E\ (b_1) = \frac{B_1\,\Sigma X^2}{\Sigma X^2 + \Sigma u^2} \ .$$

If assumptions embodied in equations 7, 8 and 11 hold, errors in the independent variable bias the value of the parameter estimate b_1 toward zero. If the three assumptions do not hold, b_1 is almost certainly biased, but the direction of bias is less clear.

Since errors in the explanatory variable invariably complicate the estimation and interpretation of least squares estimates, the best approach is to obtain accurate data. It is not possible to obtain accurate data in all instances. Methods of handling errors in the independent variables are discussed by Tintner (113, pp. 121-153) and by Fox (35, p. 32). Tintner proposes the use of weighted regression when errors exist in the variables, but all relevant variables must be included in the equation. Fox suggests adjustment of the coefficients on the basis of prior knowledge of the extent of error in the variables to compensate for the bias introduced as in equation 12. In this study, the aggregation of variables is a potential source of errors. The methods of aggregation to reduce errors in the variables are discussed extensively in the following chapter. Methods of estimating the extent of errors in the independent variables are given by Frisch (39). It is fortunate that in this study many of the variables measured least accurately are logically dependent variables.

Autocorrelation

It is necessary to distinguish between autocorrelation in the independent variables and in the error term. Autocorrelation is here defined as the correlation between a variable and lagged values of itself. Our primary concern is with autocorrelation in the residuals. Provided the other assumptions of the statistical model hold, autocorrelation results in loss of efficiency, but the estimates remain unbiased and consistent. Assuming X is fixed, the usual estimate of the variance of coefficient B_1 from equation 2 is

$$(13) \qquad s_b^2 = \frac{s_e^2}{\Sigma x^2}$$

where s_e is the standard error of the estimate. A general formula for the estimated variance of the regression coefficient is

$$(14) \quad s_b^2 = \frac{s_e^2}{\Sigma x^2} (1 + 2r_1w_1 + 2r_2w_2 + \cdots + 2r_nw_n)$$

where r_i and w_i are sets of autocorrelation coefficients (correlograms) of successive lagged values of residuals and the independent variable, respectively (134, pp. 43, 44). It is apparent from equation 14 that if no autocorrelation is present <u>either</u> in the independent variables or in the explanatory variables, equation 13 is an appropriate estimate of the variance of B_1. In economic time series, the autocorrelation coefficients of the independent variables are not expected to be zero, hence, assumption (e) of the statistical model is important. If autocorrelation is positive and high, s_b^2 in equation 13 will underestimate the variance of B_1. The t test will overestimate the significance of b_1 and result in misguided confidence in the precision of the parameter estimate.

Replicated experiments such as regression estimates from quarterly time series data are likely to be highly autocorrelated both in the independent variables and in the residuals. As observations are taken closer together, they essentially become the same observation. The result is a reduction in the effective degrees of freedom. Failure to account for the autocorrelation leads to undue confidence in the parameter estimates. If the number of "equivalent" observations in a series are known, the degrees of freedom may be reduced accordingly. Other more complex methods for estimating the effective degrees of freedom have also been devised (100).

Autocorrelation in the residuals become particularly troublesome when statistical assumption (d) is not met. The procedure often used to estimate distributed lag equations may cause this situation to exist. That is, a lagged dependent variable used as an independent variable is likely to be correlated with the residual. If residuals are non-autocorrelated, estimates derived from such distributed lag models yield consistent though possibly biased (small sample) estimates of the parameters (41, p. 72). If errors are auto-correlated, however, serious bias may arise in parameter estimates, even in large samples. The autoregressive structure of the residuals tends to be absorbed into the estimated regression coefficients. The result is biased coefficients. Tests for autocorrelation based on observed least squares residuals are not likely to detect the true autoregressive structure.

The von Neumann ratio is often used to test for autocorrelation in time series. The calculated ratio is checked against tabulated values to determine if significant autocorrelation exists. This and other tests for autocorrelation are discussed by Tintner (113, pp. 250-255) and by Hildreth and Lu (62, pp. 14, 15). A specific test for autocorrelation in least squares residuals is given by Durbin and Watson (29). This test is used extensively throughout this study. Unfortunately, the above tests are not powerful and often fail to detect existing autocorrelation, particularly in distributed lag models. To deal with the problem of autocorrelation, it is important to examine some of the sources of non-independent residuals. Cochrane and Orcutt (22) list three general sources of autocorrelated residuals: (a) incorrect form of the relationship between variables in the model, (b) omission of relevant variables, and (c) errors in the data. Time series tend to be positively autocorrelated. Also systematic errors such as improper aggregation of data lead to positive autocorrelation. For these reasons, positive autocorrelation is anticipated in least squares residuals.

If the residuals follow a first order autoregressive scheme

(15) $$e_t = A\, e_{t-1} + u_t$$

where A is the first order autoregressive coefficient and u_t is independently distributed, Cochrane and Orcutt (22, pp. 53-54) suggest the use of difference equations. The residuals of the successive difference equations may be tested for autocorrelation. They anticipate that a first difference transformation generally will be adequate. The implication of this procedure assuming an autoregressive model as in equation 15 is apparent. Assume a statistical model of the form

(16) $$Y_t = B_0 + B_1X_{1t} + B_2T + e_t$$

where Y is the dependent variable and X_1 and T (time) are independent variables. Lagging each variable in the equation one year, and subtracting the result from equation 16, we have

(17) $$Y_t - Y_{t-1} = B_1\,(X_{1t} - X_{1t-1}) + B_2 + (e_t - e_{t-1})\ .$$

If the error in equation 16 follows a first order autoregressive scheme as in equation 15 and A = 1, equation 15 reduces to

(18) $$e_t = e_{t-1} + u_t\ , \quad \text{or } u_t = e_t - e_{t-1}\ .$$

Equation 17 then may be written

$$(19) \qquad \Delta Y_t = B_1 \ \Delta X_{1t} + B_2 + u_t$$

and u_t satisfies the statistical requirement of independence. (Note that the constant B_0 in equation 16 drops out, and that the constant B_2 in the first difference equation 19 is comparable to the coefficient of T in equation 16.) In summary, estimating equation 16 in untransformed data is appropriate if A = 0 and in first differences if A = 1. The autoregressive coefficients in the real world, unfortunately, are not divided into such a dichotomy. Generally, A lies between zero and one and sometimes is less than one. Partially for this reason, Hildreth and Lu (62, p. 41) have serious reservations about the use of first differences. Their empirical results indicate that the difference transformation led to worse estimates than ordinary least squares when the disturbances are negatively autocorrelated. But even when the estimated A is greater than 0.25, Hildreth and Lu found estimates from the first difference transformation no closer than the ordinary least squares estimates to their own estimates. Their estimates are based on an autoregressive structure which allows for an unrestricted value of A. According to Watson (130), the efficiency of estimates from first differences may be low despite substantial positive autocorrelation in the true residuals. It is well to consider means other than first differences for estimating coefficients when autocorrelation is suspected in the residuals.

Fuller and Martin (41), Fuller and Ladd (40), and Hildreth and Lu (62) derive parameter estimates for single equation, least squares models assuming an unrestricted value of A, i.e. A need not equal zero or one. They apply an autoregressive transformation which essentially randomizes the residuals if equation 15 is the appropriate model. The number of significant estimates of A in the former study and the sizeable difference of the parameter estimates from the ordinary least squares estimates suggest the procedure be explored more fully.[2] Their studies emphasize the need to recognize the autoregressive structure in the residuals. An autoregressive transformation often is appropriate, and is particularly important in distributed lag equations containing a lagged dependent variable.

In this study, several methods are used to deal with autocorrelation. The most important method is to secure the most accurate and conceptually relevant data available, and to specify the algebraic form and variables in functions as adequately as possible. Failure to include relevant variables in the functions is the most important source of autocorrelation. Equations with low R^2's are most suspected of violating statistical assumption (e., other things equal.

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[2]The procedure used by Fuller, Martin and Ladd provides an estimate of the significance of the first and/or second order autoregressive coefficient. Computations are burdensome, but can be done quickly with a program designed for the high speed electronic computer.

It is interesting to note that autocorrelation was less evident in equations explaining a high proportion of the variability in the dependent variable according to the work of Fuller and Martin. However, the small number of equations makes inferences difficult.

Additional techniques than the above are employed to cope with autocorrelated residuals. In some instances, the first difference transformation is made. In other instances, the magnitude and significance of the first order autoregressive coefficient A is estimated, and appropriate adjustments are made to obtain consistent estimates despite presence of autocorrelated residuals.

Multicollinearity

The most serious limitation of time series analysis is multicollinearity (failure to meet statistical assumption (h)). We define it simply as the intercorrelation among explanatory or predetermined variables. It may also be defined as lack of independent variation in the variables. In the extreme, it results in complete degeneration of the inverse matrix of sums of squares of explanatory variables. That is, the matrix of independent variables is singular. We are unable to derive parameter estimates by the least squares algorithm because it is not algebraically possible to estimate n parameters from a matrix of order less than n. Stated in other terms, the X_i are not independent -- one or more of the X_i can be expressed as a linear combination of the other X_i. Because techniques of calculation fail when the matrix of independent variables is singular, it appears that when this occurs we simply could remove the correlated variables and proceed again to estimate the coefficients. Rarely are intercorrelations so high that estimation techniques fail. Collinearity and its consequent effect on regression estimates is a continuous relationship -- a matter of degree.

These effects are illustrated in the following example from Fox and Cooney (37). Least squares estimators are expressed in terms of partial correlations and sums of squares. The dependent variable Y_1 is considered a linear function of two independent variables X_2 and X_3. The three simple correlation coefficients between these variables are indicated by subscripts as r_{12}, r_{13}, and r_{23}. The regression equation, multiple coefficient of determination R^2, partial regression coefficients b_i and standard errors of the partial regression coefficients s_{b_i} for regression of Y_1 on X_2 and X_3 are indicated in equations 20 through 26.

(20) $$Y_1 = b_0 + b_2X_2 + b_3X_3 + e$$

(21) $$R^2 = \frac{r_{12}^2 + r_{13}^2 - 2r_{12}r_{13}r_{23}}{1 - r_{23}^2}$$

(22)
$$b_2 = \frac{r_{12} - r_{13}r_{23}}{1 - r_{23}^2} \cdot \frac{\Sigma y_1^2}{\Sigma x_2^2}$$

(23)
$$b_3 = \frac{r_{13} - r_{12}r_{23}}{1 - r_{23}^2} \cdot \frac{\Sigma y_1^2}{\Sigma x_3^2}$$

(24)
$$K = \frac{\sqrt{1 + 2r_{12}r_{13}r_{23} - r_{12}^2 - r_{13}^2 - r_{23}^2}}{(1 - r_{23}^2)\ \sqrt{n-3}}$$

(25)
$$s_{b_2} = K \cdot \frac{\Sigma y_1^2}{\Sigma x_2^2}$$

(26)
$$s_{b_3} = K \cdot \frac{\Sigma y_1^2}{\Sigma x_3^2}$$

Fox and Cooney illustrate the effect of different values of r_{23} with given values of r_{12} and r_{13}. Some of the interesting implications of their study can be observed in Table 1. In both examples $r_{12} = 0.9$, but $r_{13} = 0.9$ in example 1, 0.7 in example 2. Values of r_{23} are restricted by the requirement $R^2 \leq 1$. The b_i may be considered standardized partial regression coefficients, since $\Sigma x_1^2 = \Sigma x_2^2 = \Sigma x_3^2$. The b_i are quite stable in example 1, but the standard errors become very large at high values of r_{23}. The standard error when r_{23} = 0.999 is almost 30 times as large as when $r_{23} = 0.700$. This sensitivity in the standard errors is carried into the t

Table 1. Coefficients, standard errors, t tests and R^2's computed for various assumed values of the simple correlations between variables[a]

Simple correlation coefficients								
r_{12}	r_{13}	r_{23}	R^2	b_2	b_3	$s_{b_2}=s_{b_3}$ (n=20)	t_{b_2} (n=20)	t_{b_3} (n=20)
(Example 1)								
0.90	0.90	0.700	0.95	0.53	0.53	0.07	7.21	7.21
		0.900	0.85	0.47	0.47	0.21	2.22	2.22
		0.999	0.80	0.45	0.45	2.00	0.22	0.22
(Example 2)								
0.90	0.70	0.40	0.95	0.74	0.40	0.06	12.32	6.76
		0.80	0.81	0.94	-0.06	0.18	5.37	-0.32
		0.90	0.87	1.42	-0.58	0.20	7.19	-2.93

[a]The simple correlation between the variables is as follows: Y_1 and X_2 is r_{12}, Y_1 and X_3 is r_{13} and X_2 and X_3 is r_{23}. See text for explanation and source of estimates.

tests. For n = 20, the values of t drop from a highly significant 7.21 to a non-significant 0.22. Example 2 is included to illustrate the effect of a small change in the simple correlation r_{13} between the dependent variable and an independent variable for different values of r_{23}. In example 2 of Table 1, the standard errors appear more stable than in the first example, but the coefficients are less stable. The coefficient of X_2 behaves quite well. The coefficient of X_3, however, is highly unstable, and changes sign as the value of r_{23} increases. The coefficients of X_1 are significant at all r_{23} levels, but the instability of b_3 is imparted to the t test of that coefficient. Though $r_{13} = 0.70$, b_3 is not significant when $r_{23} = 0.80$. Table 1 indicates that the R^2 may increase or decrease with higher intercorrelation depending on the magnitude of r_{12} and r_{13}. In summary, Table 1 emphasizes the instability of regression estimates when high intercorrelations are present.

Multicollinearity is closely associated with problems of specification and of errors in the independent variables. If the true values of two independent variables are perfectly correlated, the independent influence of each on the dependent variable cannot be determined. If the sample observations of the X_i contain errors, however, the correlation between variables may be less than perfect. The individual coefficients then could be estimated, but would be meaningless. Since the presence of errors in the independent variables is not always known, these meaningless coefficients occasionally may be interpreted as structural.

It is often not possible to specify a complete model because of high correlations among explanatory variables. Although highly correlated variables individually may have very significant and different influences on the dependent variable, it is not possible to isolate these individual effects. The intercorrelation may arise when the independent variables tend to move in relation to a third variable (e.g. business or other cycles) or because the time series were too short to register independent variation in the variables. H. Schultz (104) states it is not wise to use more than four explanatory variables. Fox (35, p. 15) indicates that rarely are more than three variables used in single equation models. Thus, empirical models are highly simplified in relation to the complex, true, economic models specifying all relevant variables.

If explanatory variables were orthogonal (independent), adding and dropping variables from equations would not affect coefficients of other variables in the equation. Because intercorrelations usually are high in time series, and only a few variables may be included if the coefficients are to remain stable, there is a danger of specification error. Variables which influence the dependent variable and are correlated with independent variables are excluded from the equation and often are forgotten in the interpretation. Griliches (50, 51) shows that the expected values of coefficients in the incorrectly specified regression are equal to the weighted sum of the coefficients in the correct model. The weights are coefficients in a regression of each true or correct variable on all the variables actually used. The coefficient of X_1 might be zero in a regression because it is correlated with an omitted variable X_2 which has the opposite effect on the dependent variable. Also the coefficient of a variable having no influence on the dependent variable may be greater than zero because it is correlated with a variable which does influence the dependent variable. Researchers often have placed too much structural emphasis on a coefficient that has no exact meaning because it arises from the types of specification errors listed above.

The researcher invariably is confronted with more explanatory hypotheses (variables) than can be included in regression models. The usual procedure is to examine the simple correlations among variables before fitting the regression. Variables are excluded from the regression on the basis of simple correlations and relevance from an economic standpoint. If only one of a set of relevant variables is included in the regression, specification bias may arise and the estimated coefficients must be interpreted cautiously. A preferable procedure is to combine the correlated variables either by simple addition or by other appropriate weighting procedures. The aggregate variable then may be included in the regression.

Sometimes a large number of explanatory hypotheses are equally admissible and there is no reasonable basis for aggregating the total set into a few variables to include in the least squares regression. Collinearity precludes determination of the relative importance of each variable by statistical inference in a single large regression equation. (Although the simple correlations between explanatory variables may be low, the correlation of a linear combination of explanatory variables with one or more other explanatory variables may be high.) The procedure often used is to fit regressions with different combinations (subsets) of all the variables. The subset of hypothesis providing coefficients that are statistically significant and consistent with a priori knowledge is retained. A related procedure is to experiment with, or to add single variables until the subset giving the highest R^2 (adjusted for degrees of freedom) is found. Many of the statistical properties of least squares are enhanced by a high R^2. <u>Ceteris paribus</u>, a high R^2 not only tends to reduce autocorrelation in the residuals and least squares bias (endogenous independent variables), but also indicates smaller standard errors of coefficients and of prediction.

Two related problems arise from the procedure of experimenting to obtain a high R^2. One basic difficulty is that statistical inference is no longer valid. The probabilities upon which the statistical tests are based are biased, and lead to publication of type II errors (accepting a false hypothesis). For example, if we "sample" from 100 variables for which the true coefficients are zero, we might find by chance five coefficients significant at the 95 percent probability level. Publication of this one good equation with five significant coefficients would be a gross distortion of the true economic structure. The second problem of experimenting to obtain a high R^2 is related to the first. The confidence limits of predictions are biased. The tendency is to place too great confidence in predictions. The equation may have little structural meaning despite the high R^2 and significant coefficients, and a change in the true structure might escape the equation. The result is less accurate extrapolations than the standard error of prediction would indicate. A high R^2 also is meaningless to the extent that a major portion of it is attributed to easily predicted trend variables which do not add to the short run predictability of the equation. We are usually more concerned about predicting short run variables rather than secular trends in the dependent variable.

In summary, experimentation with different combinations of variables arises because multicollinearity forbids simultaneously testing all hypotheses in least squares. There are advantages and disadvantages of experimentation to find the best fit. The extent, if any, to which experimentation is desirable is a function of the type of problem and the judgments of the researcher.

The difficulty is not necessarily solved by a first difference transformation reducing the degree of collinearity. The basic problem -- not enough information to determine separate estimates of the true coefficients -- is not solved by the transformation. Because the simple correlations among the first differences of variables may be lower, the researcher must beware of placing undue confidence in coefficients which may result from errors in the explanatory variables.

Least squares bias

Statistical assumption (d) asserts that the residuals must be serially independent from the explanatory variables. Failure to meet this assumption results in least squares bias. From an economic standpoint, the error arises because one or more independent variables are simultaneously determined. That is, the monocausal structure postulated by the single equation least squares does not hold. One of the independent variables is endogenous, i.e. determined by a system of economic relationships. An applied problem of an interdependent structure is the classic problem of identifying the demand and supply curves from a series of price-quantity data.

A distinction should be made between two types of violations of statistical assumption (d). If a lagged endogenous variable is included as an independent variable, the least squares coefficients remain consistent and efficient in large samples, but may be biased. Inclusion of a current endogenous variable as an independent variable is more serious. The bias introduced by including more than one current endogenous variable in a least squares equation is a function of the R^2. This is readily apparent in a regression with one endogenous and one exogenous variable. As the error approaches zero (R^2 approaches one), the difference in results obtained by regressing X on Y or Y on X becomes small. Wold and Faxer (135) have shown that this conclusion applies under more general conditions in equations containing more than one independent variable.

Several techniques described by Foote (33) and others (81, 129) have been developed to estimate statistically consistent estimates of structural parameters in equations containing two or more current endogenous variables. Examples of these are recursive systems, instrumental variables, two stage least squares, full information maximum likelihood (ML) and limited information (LISE). In general, a direct relationship exists between the computational burden of the techniques and the desirable statistical properties of the estimates. Full information maximum likelihood estimates are consistent and are asymptotically efficient in an interdependent system provided the disturbances are normally distributed (84, p. 144). In a just identified structure, the other simultaneous techniques also possess the desirable properties of maximum likelihood estimates. If the system is underidentified, the foregoing techniques cannot be used to estimate structural parameters. The usual empirical applications are based on overidentified structures. (Liu (90) raises doubts about the appropriateness of this restriction and argues that economic relationships actually are under-identified.) If the economic structure is overidentified ML estimates again have certain advantages, but the other simultaneous techniques tend to provide at least consistent estimates. The limited information or Anderson-Rubin technique requires fewer computations than ML and the estimates are consistent and as efficient as other asymptotically normal linear estimates using the same or less information (84, p. 163). LISE estimates are equivalent to ML estimates which ignore the information provided by other equations about the coefficients of predetermined variables in the equation being estimated.

Consistency and efficiency are large sample properties and are of limited importance to econometricians who must always use small samples. Several Monte Carlo studies have been made to observe the small sample properties of estimators when interdependence is simulated in the data. The results of these studies have been summarized by Foote (33) and Christ (21). The studies indicate that least squares estimates are biased but display lower variance than LISE estimates when two or more endogenous variables are included in the equation but other statistical assumptions substantially are met. LISE estimates are unbiased but contain more scatter. The root mean square includes provisions for both the bias and variance and is useful for comparing techniques. Based on the root mean square, the studies indicate conflicting advantages for least squares and LISE. In several instances, LISE gave lower mean square errors and there is considerable support for the conclusion that LISE or other simultaneous techniques (two stage least squares may have some advantages over LISE) should be used when two or more endogenous variables occur in the equation. When the interdependence is not strong and when other statistical assumptions are not met, the advantages of simultaneous equation techniques are not clear.

The case for more "refined" techniques than ordinary least squares seems to resolve to a question of how much interdependence exists in actual economic structures. Unfortunately, this is not known. If there were no advantages in using least squares, the safe procedure would be to always use LISE or other structural techniques. But least squares give the best, unbiased linear estimates according to the Markoff theorem and also are computationally convenient. It would be foolish to forego these advantages if interdependence is not a serious problem.

Hildreth (60) and Christ (21) comment that empirical applications to actual data so far give no clear mandate about the usefulness of simultaneous equations. Christ's subjective impression from actual empirical applications is that the estimates from ordinary least squares and LISE do not differ grossly in many cases. He adds that where they differ, it is the LISE rather than least squares estimates that are unreasonable on the basis of economic theory and empirical evidence. Waugh (132, p. 392) expresses his belief that a collection of "actual forecasts (or estimates) would show that those from least squares equations were definitely superior to those from structural equations".

Why estimates from structural equations have not always been found satisfactory can be attributed to several factors. LISE estimates, for example, appear to be more sensitive than least squares to departures from the underlying statistical assumptions other than (d). Limited information estimates sometimes involve large structures and the matrix of endogenous variables regressed on all predetermined variables in the system may approach singularity. The result is a particular sensitivity of the system to changes in specification. It is only natural to specify most completely (include most variables in) those equations in which we have the greatest interest. The paradoxical result is that we may very likely obtain the poorest estimates from these equations because of a tendency for underidentification and multicollinearity. Finally, LISE techniques are often unwieldy and sometimes it is not possible to experiment with different specifications until one gets good results. This may be an advantage of LISE since it reduces the incidence to type II errors, but it may not be apparent to the person reviewing the relative merits of models from the literature on applied research.

In a number of structures considered in this study, the economic relationships logically resolve to equations containing only one endogenous variable. In many instances, a priori logic does not clearly dictate the statistical procedure. Where the rationale for ordinary least squares is tenuous, limited information and recursive techniques are utilized in the empirical applications of the following chapter. Evidence builds slowly from repeated applications, but it is hoped that the results from the various procedures will aid in evaluating the extent of interdependence in agriculture and the necessity to use empirical tools which recognize this interdependence.

Other statistical assumptions

The remaining statistical assumptions (c), (f) and (g) are not considered crucial. The desirable features of least squares estimates hold in general if the error follows some probability distribution, not necessarily the normal distribution (33, p. 58). If it is suspected that the errors are heteroscidastic, i.e. non-homogeneous over time, the estimates remain consistent and unbiased but efficiency is lost. A procedure sometimes appropriate for correcting heteroscidasticity is to transform the data into logarithms. The error structure then becomes multiplicative rather than additive.

We have placed major emphasis on structural rather than predictive relationships in this chapter. If the purpose of an analysis is a positivistic prediction of a variable in an environment free of autonomous influences (e.g. government action) and subject only to random shocks, many of the above statistical assumptions may be ignored. If the forces in the economic structure that determines the magnitude of a variable move similarly through time, the variable can be predicted precisely without knowledge of the underlying structure. The most precise prediction in this setting probably would be made by a least squares equation including the maximum feasible number of known independent variables without regard for collinearities and interdependence. In this study, it is necessary to obtain some estimate of the structural parameters. That is, it is necessary to gage the influence of manipulation of a single variable in a structure on the magnitude of some other variable in the structure. Knowledge of the parameters of the structural variables is desired. It should be noted that this does not necessarily lead to rejection of ordinary least squares and to acceptance of limited information or similar techniques.

CHAPTER 4: DATA AND AGGREGATION

Statistical inferences rest not only on appropriate models and significant results, but also on the reliability of the data. Although the most advanced techniques are employed, we have little confidence in the results if the underlying data are inadequate. Our purpose in Chapter 4 is to discuss the nature of the data used in this study. The sources and reliability of the data are discussed in the first section. Whenever possible, published data are used directly in the models. But often the available quantity series are not comparable with the price series or the published series do not conform to the desired aggregation. Thus, a section is devoted to aggregation procedures; to illustrate criteria and procedures used for aggregating data in this study. It is also hoped that this section will have some pedagogic value. The final section contains a comparison between direct expenditure and income series of the United States Department of Agriculture (USDA) and comparable estimates from price and quantity aggregates used in the structural models of this study. These comparisons provide an approximate test of the data and aggregation procedures employed.

Sources and Reliability of Data

The data on resource quantities, prices and expenditures are from published and unpublished sources of the Agricultural

Marketing Service (AMS) and of the Agricultural Research Service (ARS) of the USDA. The structural model is estimated from aggregate estimates for the United States due to lack of data by region and economic classification. Thus, we abstract from problems of differential structural parameters by region and type-of-farm.

One cannot give an accurate categorical appraisal of the reliability of data used in this analysis. The data can only be judged by individual categories on the basis of sampling techniques, methods of aggregation and the conceptual purpose of the estimates. Since sampling errors and other statistical measures of reliability are unavailable, considerable reliance is placed on personal judgment based on a description of collection procedures, what is being measured, etc.

Price and expenditure series

The prices used in structural models are compiled by the AMS. The purpose of the AMS compilation is to provide a measure of prices paid by farmers for items "commonly purchased". This concept is designed for comparisons over time of farmers buying power expressed in the parity ratio. The concept of what is "commonly purchased" is not consistent with the concept of input measurement needed for structural analysis. To avoid "hybrid" functions, it is necessary that resources remain unchanged, at least within the time period considered. If a Chevrolet is "commonly purchased", the prices in 1926 and 1959 are not comparable because of quality and/or technological improvements in the later model which increase the price. The effect on estimates of quantity or physical volume is described in the following section.

The AMS relies mainly on voluntary replies to mailed questionnaires for input price information. The response to the questionnaires generally ranges from 10 to 50 percent for tested lists of reporters (116, p. 34). Inquiries are directed also to merchants in small towns and other dealers who have current knowledge of input prices. These reports are supplemented by estimates from hatcheries, Market News Service, local governments and the Farm Credit Administration.

The AMS uses a modified Laspeyres or weighted aggregate index (the index W illustrated in the next major section) to combine input prices. Since quantity weights are not readily available for each year, the weighted aggregate index is convenient. From 1910 to March 1935, the base period is 1924-29; after March 1935, the base is 1937-41.

Expenditure data are collected by widely different methods. Considerable reliance is placed on benchmark data from the census or from detailed surveys. The benchmark figures are supplemented by mailed surveys and by estimates computed from related data which are already available. For example, expenditures for petroleum fuel and oil are from the agricultural census for 1939, 1949 and 1954. Estimates for other years are projected from these benchmark totals on the basis of petroleum product prices, number of motor vehicles on farms, and average consumption of fuel and oil by each type of motor vehicle (119, p. 18). Capital expenditures are the sum of depreciation, interest charges and accidental damage. This is a somewhat subjective measure based on a proportion of total inventories. Inventories are estimated from benchmark census estimates supplemented by data from manufacturers' shipments, assessors' reports and farm surveys.

Estimates of expenditures on minor inputs often are tenuous. Methods of estimation differ markedly, and it is impossible to discuss each individually. From the detailed explanation in Agricultural Handbook 118 (119, p. 29), we present only the following summary:

> When the census or frequent surveys provide adequate benchmarks, and really relevant information on changes in quantity and price for the item in question are collected for other years as well, expenditure estimates are fairly accurate. This is true in the case of cash wages to hired labor, livestock purchases, fertilizer and lime, property taxes, farm-mortgage interest payments, and some miscellaneous operating expenses.

Quantity series

The quantity measures used in the empirical models of this study are mainly the unpublished constant dollar values from the new index of inputs compiled by Glen Barton (4, 5) to measure aggregate productivity (output-input ratio) in agriculture. The concept of the farm firm employed in the aggregate model of this study closely approximates that used by Barton, i.e. all of agriculture is regarded as one large farm. The farm value of interfarm transfers of feed, seed and livestock are excluded. Since aggregation of heterogeneous inputs is necessary, constant dollar "quantities" or values are used. Whenever possible, Barton estimated constant dollar values from physical quantities multiplied by base period prices. In many instances, the value of inputs were estimated from expenditures deflated by implicit prices (5, p. 1399). Barton then aggregated inputs by weighting "quantities" prior to 1940 by 1935-39 prices; after 1940 by 1947-49 prices. Overlapping observations for 1940 allowed splicing of the two periods so that the entire aggregated series was expressed as a percent of the 1947-49 average index.

Aside from index number problems described later, the use of implicit price deflators may bias the quantity estimates, particularly if the quality of inputs has increased. If changes in input quality increase prices, dividing expenditures by prices may result in distorted estimates of the quantity. Griliches (49) criticized the USDA's new input series for inadequate provision for quality changes. He makes the following revisions in input levels for the period 1940 to 1958 due primarily to quality changes in inputs: (a) The capital services (machinery, livestock, inventories, etc.) are increased 30 percent; repairs and operation of capital equipment 26 percent. (b) The index of labor input is increased eight percent due to additional education of farm labor. (c) The fertilizer and lime index is increased six percent to reflect the gradual shift to fertilizers with higher nitrogen content. After other general revisions of input indices, he concludes that the index of total inputs increased 15 percent from 1940 to 1958 -- 12 percent more than the USDA estimate. Consequently, productivity increased approximately 12 percent less by the Griliches data than by the USDA data. Masucci (91) feels that Griliches overadjusted the input data, and that if similar adjustments for quality are made in the output series, the error in measuring productivity would be around five percent.

To summarize with an ordinal classification, the price data are the most accurate statistics in the models. The expenditure data are less reliable than the price series. Since the quantity data are derived to a considerable extent from prices and expenditures, they are least reliable. In general, dairy supplies, binding materials, small hand tools, pesticides and other miscellaneous items are estimated from the least information; therefore are subject to the largest errors. These minor inputs are aggregated into a miscellaneous category. If errors are not extensively correlated, the total percentage error in the index may be small in relation to the percentage error in each component series. That is, errors may offset each other to some degree. Also, qualitative changes have been few for many minor inputs and may be a less significant source of error than for major inputs such as machinery.

The limitations of the data are discussed to give proper perspective to the final empirical estimates. The restricted research resources for this study preclude modification of the data for quality changes and other distortions. It should be emphasized that the USDA has done a good overall job of securing and processing data with their available resources. Where series are not suited for this analysis, it is because the data conceptually are designed for other uses, or because resources for gathering the data were too limited.

Aggregation -- The Use of Index Numbers

In prescribing the consequences of alternative courses of action, the economist necessarily must condense the multifarious, often inconsistent, and random-appearing behavior of individuals into a few meaningful, consistent relationships useful for predictive purposes. To avoid grouping farm inputs, one would need to distinguish between brands of tractor tires and grades of oil. Time periods would need to be so short that quantities within a period could be regarded as perfect substitutes. Clearly, aggregation over time, commodities and production units is both desirable and unavoidable. It is desirable to the extent that policy makers desire information on how <u>total</u> income, <u>total</u> employment and other aggregates are influenced by alternative actions. It is also desirable to the extent that there exists regularities in mass behavior. It is unavoidable to the extent that: (a) data are made available only on an aggregated basis because of cost considerations, and (b) analytic models are incapable of handling large numbers of variables.

The question of how to aggregate is dictated to some extent by the availability of data. But where a decision on aggregation must be made, the criteria for what commodities, production units and time periods to include depends on what use is to be made of the estimates. If a comparison of <u>investment</u> expenditures in U.S. agriculture between 1920 and 1960 is desired, aggregation of such diverse elements as tractors and fertilizer may be justified. In other instances it may not be feasible to combine such related inputs as nitrogen and phosphate fertilizers. The comparisons of aggregate inputs, output and productivity over time and the construction of dependent variables in production, demand and supply functions falls logically into framework of index numbers. The weighting procedures unique to economic relationships (e.g. the independent variables in demand and supply functions) largely can be superimposed upon the index formulations. Thus, index number aggregation formulae and tests are considered in this section. Aggregation in economic relationships are considered in the two following sections. The discussion is oriented to the aggregation and data requirements of this study.

The theory of index numbers arose from the need to estimate changes in the price level and real income over time. Despite the substantial development of theoretic criteria to evaluate cost-of-living indices, only in the postwar period has any significant effort been made to apply these theoretic criteria to indices of physical output and efficiency. Notable contributions in this area have been made by Simpson (106) and by Ladd (87). Several criteria for evaluating cost of living indices are adaptable to evaluation of input quantity and price changes through time. To understand the criterion and the theoretic work of Simpson, Ladd and others, it is necessary to consider some basic formulations in making comparisons over time. If we wish to make a binary (between two years) comparison of all capital inputs used in agriculture, it is necessary to combine items which cannot be combined logically on a purely physical basis. It can be demonstrated that under certain assumptions, weighting the component physical inputs by prices gives a "true" measure of actual change in aggregate quantity (28, pp. 333-335). How to weight the quantities by prices to obtain the "true" quantity change remains a subject of considerable discussion.

Types of indices

The Laspeyres formula, $L = \frac{\Sigma p_0 q_1}{\Sigma p_0 q_0}$, is a ratio of current quantity q_1 to base year quantity q_0 weighted by base year prices p_0. The Paasche formula, $P = \frac{\Sigma p_1 q_1}{\Sigma p_1 q_0}$, is a ratio of current year quantities to base year quantities weighted by current year prices p_1. If prices remain unchanged between years, the two formulae give the same measure of quantity change. Unfortunately, because relative prices and, hence, weights change from period to period, one is faced with choosing between the two formulae or of choosing alternative weighting procedures. The two formulae are of equal logical basis for estimating changes in aggregate quantities. They are equally good in the sense that together they utilize all the information available for judging the quantity change and they establish the upper and lower limits of the change. But they are equally bad because neither utilizes all the price and quantity information. Various combinations of index formulae have been developed as an improvement on the Paasche and Laspeyres. Perhaps most notable is the "Ideal" index F which is the geometric mean of the two, i.e., $F = \sqrt{LP}$. The Ideal index possesses desirable properties which will be apparent later, but these properties may have little economic significance (28, p. 328).

Evaluation of weighting procedures

The most extensive evaluation of index formulae was made by Fisher (32) who applied several criteria in attempting to choose the "best" index from 134 formulations. These criteria such as the time and factor reversal tests are applied to determine the appropriateness of weighting procedures used in aggregating quantities and prices in this study. The consistency test, illustrated by Mudgett (96, p. 50) also is appropriate and is considered first. The measure of formula consistency is $D = L - P$ where L and P are the Laspeyres and Paasche indices. Mudgett concludes that if $D < 2$, either L or P is a satisfactory weighting procedure, but if $D > 20$, it appears that no satisfactory measure of the change is possible. In such instances, it may be necessary to abandon the project of aggregate comparison. We apply the consistency criterion D to test the feasibility of aggregating the quantity of motor vehicle purchases Q_{MV} and machinery and equipment purchases Q_{ME} into an aggregate measure of farm machinery purchases Q_M. The quantities to be combined are themselves aggregates, but for present purposes they are considered single commodities with appropriate prices P_{MV} and P_{ME}. Also a base period (1947-49) rather than a base year is used, thus, the formulas are not strictly Laspeyres or Paasche, but are "weighted aggregates". The criteria remain applicable, however. Table 1 shows the indices of quantities computed by the Laspeyres L, Paasche P and Ideal F formulae. The fourth type W, is the procedure used throughout this study. Quantities

Table 1. Price indices for all farm machinery P_M computed by Ideal F, Laspeyres L, Paasche P and modified Laspeyres W formulae[a]

Year	Price index (1947-49 = 100)				
	W	F	L	P	D=L-P
1925	55.20	55.41	55.82	55.00	0.82
1930	55.20	55.49	55.64	55.35	0.29
1935	56.10	55.53	56.12	54.95	1.17
1940	59.53	59.23	59.53	58.93	0.60
1950	112.34	112.30	112.34	112.27	0.07
1955	126.47	126.40	126.47	126.33	0.14
1959	150.24	150.38	150.24	150.52	0.28
% increase 1925 to 1959	172.17	171.40	169.15	173.67	

[a]The indices are defined in the text. The component price series are farm machinery prices P_{ME} and motor vehicle prices P_{MV} published by Agricultural Marketing Service (120). Quantity weights from unpublished sources (4).

(prices) prior to 1940 are weighted by 1935-39 prices (quantities). After 1940, quantities are weighted by 1947-49 prices. The two base periods are linked with overlapping observations for 1940 to make the entire quantity (price) index equal 100 for the 1947-49 period. This procedure is intended to insure against large bias due to an extensive change in weights over the period considered. It may be noted that W=L after 1940. The procedure often is used by the USDA to construct price indices because current quantity weights are not available for P and, therefore, for F formulae. The Laspeyres formula indicates a 169.15 percent increase in prices of farm machinery from 1925 to 1959. The Paasche formula shows a slightly greater increase over the same period, 173.67 percent. The relatively small difference in increase depicted by the two indices probably is much smaller than differences which arise due to sampling error in the data. The consistency formula D indicates a small error ranging from 0.07 in 1950 to 1.17 in 1935, well within the margin of consistency suggested by Mudgett.

The quantity index in Table 2 also depicts comparable

Table 2. Quantity indices for all farm machinery Q_M computed by Ideal F, Laspeyres L, Paasche P and modified Laspeyres W formulae[a]

Year	Quantity index (1947-49 = 100) W	F	L	P	D=L-P
1925	37.29	36.90	37.17	36.63	0.54
1930	37.15	36.76	36.86	36.66	0.20
1935	33.02	32.85	33.20	32.51	0.69
1940	43.08	42.86	43.08	42.64	0.44
1950	104.89	104.86	104.89	104.83	0.06
1955	82.75	82.70	82.75	82.66	0.09
1959	83.30	83.38	83.30	83.45	0.15
% increase 1925 to 1959	123.38	125.86	124.11	127.82	

[a]The indices are defined in the text. See Table 1, footnote a, for sources of price and quantity components.

estimates by the various weighting procedures. The Ideal index F always lies between L and P by construction. The consistency formula D in Table 2 again indicates a small error -- less than 1.00 in all instances. The results indicate that either the L or P formulae are adequate to express price and quantity changes. The respective price and quantity weights have not changed to a sufficient degree to bias significantly the estimates of aggregate change. The results further emphasize that since D is small, it is feasible to make aggregate comparisons of prices and quantities of farm machinery over time.

Two additional tests, used extensively by Fisher, are the factor reversal test and the time reversal test. The factor reversal test R indicates the ability of price index multiplied by the quantity index to measure the actual expenditure index. For the Laspeyres index L, the factor reversal percentage error R_L is

$$(1) \qquad R_L = \frac{L_q L_p}{V} - 1$$

where L_q and L_p are quantity and price indices respectively and V is the expenditure index, $V = \frac{\Sigma p_1 q_1}{\Sigma p_0 q_0}$, for the same base period.

Table 3 indicates one important reason why Fisher classified the Ideal formula as superlative -- the factor reversal error is zero. The error R in the formula used in this

Table 3. Expenditure indices for all farm machinery E_M and factor reversal errors R computed by Ideal F, Laspeyres L, Paasche P and modified Laspeyres W formulae[a]

Year	Expenditure index (1947-49 = 100)								
	W	R[b]	F	R	L	R	P	R	V
1925	20.58	0.64	20.45	0.00	20.75	1.47	20.15	-1.47	20.45
1930	20.51	0.54	20.40	0.00	20.51	0.54	20.29	-0.54	20.40
1935	18.52	1.54	18.24	0.00	18.63	2.14	17.86	-2.08	18.24
1940	25.65	1.02	25.39	0.00	25.65	1.02	25.13	-1.02	25.39
1950	117.83	0.06	117.76	0.00	117.83	0.06	117.69	-0.06	117.76
1955	104.65	0.11	104.54	0.00	104.65	0.11	104.42	-0.11	104.54
1959	125.15	-0.18	125.38	0.00	125.15	-0.18	125.61	0.18	125.38
% increase 1925 to 1959	508.11		513.11		503.13		523.37		513.11

[a]The expenditure indices are the products of the respective price and quantity indices. These indices are defined in the text. See Table 1, footnote a, for sources of price and quantity components.

[b]The formula for R is given in the text. As with price, quantity and expenditure indices, the factor reversal error R is converted to a percent.

analysis W is less than the error in the L or P indices prior to 1940. From 1940 to 1959, W = L, hence, R for two indices are equal. The factor reversal error is as high as 2.14 percent for the Laspeyres index and 2.08 percent for the Paasche index in 1935. It is apparent that the D and R tests are related; when D is large in 1935 (Tables 1 and 2) R is also large (Table 3). The relationship between the D and R tests is determined by computing the factor reversal errors in the Laspeyres index R_L in terms of L and P indices:

$$(2) \qquad R_L = \frac{L_p L_q}{V} - 1 \ .$$

Since $V = F_p F_q = \sqrt{L_p P_p}\ \sqrt{L_q P_q} = \sqrt{L_p L_q}\ \sqrt{P_p P_q}$

$$(3) \qquad R_L = \frac{L_p L_q}{\sqrt{L_p L_q}\ \sqrt{P_p P_q}} - 1 = \sqrt{\frac{L_p L_q}{P_p P_q}} - 1 \ .$$

If D = 0, L = P, hence $R_L = 0$. This conclusion applies as well to the factor reversal error for the Paasche index, R_P. If the consistency test indicates that D is small (relative weights have not changed appreciably over the time period) we may conclude that the factor reversal test R also will indicate a small error.

The factor reversal errors for L and P in Table 3 are equal with the exception of 1935. The exact relationship between the errors can be found from equation 3 to be

$$(4) \qquad \frac{R_L}{R_P} = -\sqrt{\frac{L_p L_q}{P_p P_q}} \ .$$

It follows that as the Laspeyres expenditure index L_pL_q approaches the Paasche expenditure index P_pP_q, the ratio of factor reversal errors approaches one. Though L_pL_q is not equal to P_pP_q for any year in Table 3, the difference is so small that rounding decimals results in equal factor reversal errors, or $R_L/R_P = 1$ except in 1935.

A third test of the aggregation procedures used in this publication is the time reversal test T. The test measures the extent of error resulting from a change in the base year or period. To be accurate, a formula must be independent of the base, i.e. T = 0. If an index for 1959 with base 1940 equals 150, then the index for 1940 with base 1959 should equal 67. The time reversal error for the Laspeyres formula T_L applied to farm machinery data for the base periods 1935-39 and 1947-49 is about one-half of one percent. That is, T_L = 0.57 percent. It can be shown that T_L is equal for the price and quantity indices, thus only one need be considered. The time reversal error for the Paasche index T_P may be computed directly from Laspeyres index T_L. Since

(5) $T_L = L\ (35\text{-}39,\ 47\text{-}49)\ L\ (47\text{-}49,\ 35\text{-}39) - 1 = LL-1$,

it follows that

$$(6) \qquad T_P = \frac{1}{LL} - 1 = \frac{1-LL}{LL} = -\frac{T_L}{T_L + 1} .$$

It is apparent that as T_L becomes small, T_P approaches T_L (both approach zero). T_P approaches one as T_L becomes large. Applying the formula to the farm machinery aggregate,

T_L = 0.573% or 0.00573. Thus, $T_P = \frac{-0.00573}{1.00573}$ or -0.00570 = -0.57%. The time reversal error again is small. Only the time periods 1935-39 and 1947-49 are considered, but since the data extend only ten years beyond the extremes of these periods, the single time reversal test is considered adequate.

The formula error estimated by D, R and T is small in the aggregation of equipment and motor vehicles into a single measure of farm machinery. The errors are not independent and, therefore, non-additive. We may conclude that for most years the formula error is less than two percent, and is probably small relative to sampling error. Other aggregations are made throughout the analysis. In most instances, the formula error is larger than that in the foregoing example since the relative weights change considerably. Where a wide range of commodities are aggregated, e.g. aggregation of all inputs in agriculture, bias may be considerable. Ladd (87) has considered the direction of such bias from a theoretic standpoint for (a) the index of aggregate inputs and (b) the technological index or ratio of aggregate output to aggregate input. He concludes that the index of physical volume of inputs is biased upward due to relative price changes. The technological index is biased downward because of changes in relative factor and/or product prices. This bias is at least as large as would exist if either change occurred alone. That is, the biases cannot offset each other. The technological index can equal unity only when the production function is homogeneous of degree one. The index need not exceed one even when technology does improve (87, pp. 80-85).

Selection of an index formula

What index formula should be used to aggregate several items for comparisons over time? Simpson (106) states that in certain instances the Ideal formula will give a better approximation than the Laspeyres or Paasche. Bergstrom (10) suggests that L, P and F be computed if costs may be ignored in constructing indices for use in economic models. If the results from the three types of indices are comparable, only the results from one index need be presented. If this method is too costly, he recommends the Ideal index since it will be better than at least one of the Paasche and Laspeyres indices.

The foregoing analysis indicates certain desirable qualities of the Ideal formula. Examples are (a) the absence of factor reversal error, (b) utilization of all price and quantity information and (c) the intuitive appeal of a formula which is an average of extremes, i.e. the Laspeyres and Paasche. The modified Laspeyres index W with two base periods linked at 1940 also gives results generally between L and P in the foregoing tables. Like the Ideal, W also avoids some of the distortion which may result because of changes in relative weights. It is also easily calculated. The USDA uses the W type index extensively in the component series on prices, quantities and output used throughout this study. There is some advantage in preserving uniformity in index procedures used in the aggregate and component series. For these reasons, we shall rely mainly on the index W in combining price and quantity series in this study.

Aggregation in Production Functions

Statistical limitations prohibit inclusion of many variables in the production function. This raises the question of what aggregation of inputs is consistent with minimum bias in the parameters. The aggregation of inputs in the production function is discussed by Plaxico (101) and by Heady and Dillon (56, pp. 215-217, 228, 229). Two working rules emerging from these studies and from Bradford and Johnson (16, Chapter 10; and Appendix, Chapter 12) are: (a) Perfect complements must be combined into one input. A statistical law such as least squares cannot isolate the relative contribution to output of separate inputs used in fixed proportions. One input is a linear combination of the other -- the problem of multicollinearity discussed earlier. (b) Perfect substitutes must be weighted and combined as a single input.[1] The weights are

[1]The correlation between inputs which are perfect substitutes is minus one, between perfect complements is plus one. To avoid a singular input matrix in least squares regression, the highly correlated inputs must be combined.

proportional to the marginal rate of substitution which in turn equals the relative price ratio in equilibrium. We are back to the index number weighting methods discussed in the previous section. Aggregation of perfect substitutes is equivalent to combining inputs which have the same influence on output.

When the Cobb-Douglas form of the production function is used, geometric rather than arithmetic aggregation is suggested (cf. 56, 79). Geometric aggregation not only reduces bias in Cobb-Douglas production elasticity estimates, but also allows the researcher to ascertain the extent of bias in the parameter estimates. Weighting component inputs by respective elasticities of production would result in perfect aggregation. The elasticity of production for each component is seldom known, however.

In this study, machinery and motor vehicles are considered complementary inputs and are combined to form a single input. Complementarity among fertilizer, seed and other operating items suggests combining these into a single category -- operating inputs. Inputs within the components such as sizes of tractors are considered sufficiently substitutable to warrant aggregation. Other combinations of inputs are employed in the production functions estimated in Appendix A.

Aggregation of Economic Relationships

Most economic policy decisions are made on the basis of aggregate behavior. Yet economic theory which helps to answer questions asked by policymakers is based mainly on the theory of the firm. If research resources were abundant, the researcher could obtain very accurate estimates of the effect of a rise in farm income on farm machinery purchases, for example, by surveying the increase for each farmer and summing these results. This approach is seldom possible. Rather, the relationship between income and machinery purchases must be estimated from aggregate income and sales data. Serious discrepancies can arise in predicting machinery purchases from the latter aggregate method. The question arises -- how can the economist use the aggregate approach, yet achieve consistency with the micro or individual farm approach? Two alternatives are: (a) estimate the macro <u>parameter</u> (e.g. marginal propensity to invest) from macro <u>variables</u> formed from micro variables weighted to insure consistency, and (b) analyze the type of underlying economic relationship which must necessarily hold to allow consistent statistical estimation and prediction from "simple", available aggregates. "Simple aggregates" may be an arithmetic sum of homogeneous inputs or weighted sums (by index formulae) of less than homogeneous data. Consistent estimates would then be achieved by estimating economic relationships only from simple data gathered from an environment satisfying the aggregation criteria. Alternative (a) is attributed to Klein (79) and is represented by the criterion for "perfect aggregation" established by Theil (110). The second alternative (b) is attributed to May (93).

Criteria for economic aggregation

Problems of economic aggregation have been considered extensively by Theil (110) and have been extended and clarified by Allen (1) and Foote (33, pp. 84-87). A short example will illustrate some of the concepts necessary to gain consistent predictions. Let us consider the demand quantity of farm machinery Q to be a linear function of income Y for each farmer i. The marginal propensity to invest in machinery is b_i for farmer i. The most accurate and, unfortunately, the most costly and time consuming method of determining the change in quantity purchased arising from a change in income is to sum increments over all farmers, i.e.

$$(7) \qquad \Sigma \Delta Q_i = \Sigma b_i \ \Delta Y_i \ .$$

To reduce costs of predicting the change, it would be desirable to estimate the change in quantity from a macro equation

$$(8) \qquad \Delta Q = b \ \Delta Y$$

where Q is the estimated total increase in demand quantity and Y is total income. Ordinarily

$$(9) \qquad b \ \Delta Y \neq \Sigma b_i \ \Delta Y_i \ ;$$

therefore,

(10) $$\Delta Q \neq \Sigma \Delta Q_i$$

and the micro and macro methods of estimation are not consistent. It is possible to make them consistent with two assumptions. The first is that the increase in income for farmer i is proportional to the aggregate increase in income (no redistribution of income), or

(11) $$\frac{\Delta Y}{\overline{Y}} = \frac{\Delta Y_i}{\overline{Y}_i}$$

and the second assumption is that b is weighted by the average propensities to invest, or

(12) $$b = \frac{1}{\overline{Y}} \sum b_i \overline{Y}_i \ .$$

Substituting the assumptions of equations 11 and 12 into the left side of equation 9, we find

(13) $$b \ \Delta Y = \sum b_i \ \Delta Y_i$$

and the micro and macro predictions are consistent. The above example is equivalent to the concept stated by Hicks (59, p. 313) that "if all prices of a group of goods change in the same proportion, that group of goods behaves just as if it were a single commodity".

Theil (110) describes a method of <u>perfect</u> <u>aggregation</u> of individual demand relationships into a single macro demand function which avoids all contradiction in prediction. The procedure is to weight the income Y_i for each farmer by his respective marginal propensity to invest b_i. The macro income variable is a weighted average income, the weights being the marginal propensities to invest b_i. The macro equation then provides the same estimate of purchases as the sum of the purchases over all micro units. It also follows that if the marginal propensities to invest were the same for each farmer, the simple and weighted average income would be the same. If the marginal propensities to invest were homogeneous for each of the individuals in a group, the macro demand quantity could be predicted from a simple aggregate income variable in a single macro equation.

The foregoing discussion has been centered on aggregation over farms, but the principles can be generalized for aggregation over time or commodities. When aggregation takes place over non-homogeneous commodities, the index number problem arises. For example, the quantity Q in equation 7 may be aggregated by prices if corn pickers and grain combines are included. If prices rather than income is the independent variable, prices must be weighted by quantities. The index formula suggested earlier may be appropriate. For "perfect aggregation", prices must <u>also</u> be weighted by individual price elasticities. It is apparent that the criteria for economic aggregation largely are superimposed on the index number criteria.

The criterion for aggregation suggested by Glenn Johnson (72) is closely related to the foregoing principle of aggregating quantities which display similar responses to income or other stimuli. Johnson groups resources in a manner to explain agricultural output. He aggregates resources which are relatively homogeneous regarding attributes which determine movement between the farm and the non-farm sector. The criterion for movement (or fixity) of resources is the nature of salvage values and acquisition costs. Based on this criterion, he arrives at the following categories of farm resources:

(a) Non-farm produced durables -- tractors, combines, tiling, etc.

(b) Unspecialized farm durables -- fence posts, pasture seedings, soil improvements, etc.

(c) Specialized farm durables -- dairy cows, orchards, sows, ewes, beef breeding stock, etc.

(d) Unspecialized farm expenditures -- corn, hay, etc.

(e) Specialized farm expendables -- seed corn, grass seeds, etc.

(f) Non-farm expendables -- fuel, oil, and commercial fertilizer, etc.

(g) Hired labor

(h) Family and operator's labor

(i) Land.

The criteria established above for aggregating economic variables obviously cannot be fulfilled completely in practice, but do provide a useful guide to aggregation in subsequent sections. Theil's "perfect aggregation" is not feasible since in most instances the micro parameters are unknown and considerable costs are involved in their estimation. For the most part, it is necessary to rely on simple aggregates of prices, quantities and income based on index number procedures when the variables are non-homogeneous. In the previous section, we observed that reasonably consistent results are obtained by simple aggregation if inputs are grouped which are relatively homogeneous with respect to the variables which influence the economic relationship. That is, it is feasible to combine inputs in a demand function if the demand quantities are influenced by the same variables, the magnitudes of the coefficients of these variables are similar, and prices change approximately in the same proportions. This aggregation is not only feasible but also is necessary in a single equation or simultaneous system estimated by limited information since the matrix of exogeneous variables must be non-singular.[2]

In general, prices of current operating inputs have increased least over time, prices of labor and machinery have increased most. Current operating inputs such as seed and fertilizer are short run expendables, completely consumed in

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[2]The matrix of coefficients of endogenous variables must be non-singular in the limited information model (84, p. 118). Improper aggregation could violate this condition also.

the production process. It may be hypothesized that the components tend to be influenced similarly by the same variables. For these reasons, operating inputs are placed in a single input category in the simultaneous model. Furthermore, it is felt that the economic relationships affecting motor vehicles and other farm machinery are sufficiently similar to aggregate them into a single category. Many individual components of these aggregates are considered also in single equation demand functions.

It is sometimes necessary to accept the grouping already established by the USDA. The categories used by the USDA conform reasonably with the aggregation criteria established above. Data limitations require use of some input groups which are aggregated over types of farms, economic classes and regions in violation of the aggregation criteria.

Resource categories analyzed in this study

The economic structure is estimated for the input categories listed below. The groupings are based on the foregoing aggregation criteria. Demand and supply functions are estimated by limited information single equations for the categories designated LISE. Demand functions are estimated by single equation least squares for categories indicated by LS. To preserve parallelism with the concept of farm output, inter-farm sales of seed, feed and livestock are excluded from aggregate operating inputs. Only inputs used for production are included. The categories analyzed are as follows:

(a) Current operating inputs (LISE and LS). This category is composed of the non-farm purchases of seed (LS), fertilizer and lime (LS), repairs of buildings (LS), repairs, fuel and oil for farm machinery (LS), feed (LS), livestock and finally, miscellaneous inputs (LS). The individual least squares demand equations for feed and seed include inter-farm sales.

(b) All farm machinery (LISE and LS). This category includes motor vehicles (LS) and other farm machinery and equipment (LS).

(c) Total farm investment (LS). The measure includes investment in building improvements (LS), all farm machinery, livestock and feed inventories, and cash held for productive purposes. The demand for a less aggregate measure of durable goods, all farm machinery plus building improvements, is also estimated by least squares.

(d) Total farm labor. The hired labor (LISE and LS) and family labor (LS) components are investigated.

(e) Agricultural supply (LISE and LS) and output (LS) functions are estimated directly and also are explained on the basis of parameter estimates from the input functions.

Consistency between Price-Quantity and Expenditure Data

As an additional explanation of the price and quantity concepts used in this study, and as a measure of the errors in aggregation, the major price and quantity data used in the aggregate structural model are presented for 1955 to 1959. Ultimately, we are concerned with the ability of the price and quantity series to measure gross income, expenditures and net income. If the price and quantity series compiled for use in the aggregate model provide estimates of income and expenditures comparable to the direct estimates found in The Farm Income Situation (FIS) (121), then we are more confident of the underlying data and aggregation. The 1955-59 period is chosen because the recent years are of most interest in the model for predictive purposes. The period also is considerably removed from the 1947-49 base, thus, may reveal discrepancies due to changing price and quantity weights.

Table 4 contains estimates of prices, quantities and expenditures for current operating inputs and all farm machinery. Price P_O and quantity Q_O are those used in the simultaneous model. The operating expenditure $P_O Q_O$ is somewhat less than expenditures indicated by the FIS due to omission of inter-farm sales of seed, feed and livestock. The farm machinery expenditures $P_M Q_M$ are similar in concept to those in FIS. Table 4 shows that the two sources give similar

Table 4. Aggregate prices, quantities and expenditures on current operating inputs and on all farm machinery from 1955 to 1959

	Current operating inputs[a]				Farm machinery[b]			
	Price[c]	Quantity[d]	Expenditure		Price[d]	Quantity[d]	Expenditure	
	P_O	Q_O	$P_O Q_O$	FIS[e]	P_M	Q_M	$P_M Q_M$	FIS[e]
Year	1947-49 =100	$Million (1947-49)	$Million (Current)	$Million (Current)	1947-49 =100	$Million (1947-49)	$Million (Current)	$Million (Current)
1955	108.9	7709	8264	12,793	126.5	2125	2688	2591
1956	107.2	8037	8600	13,385	130.8	1757	2298	2281
1957	107.0	8084	8755	13,908	139.2	1711	2382	2378
1958	108.3	8423	9088	15,386	145.2	2068	3003	2961
1959	107.9	8895	9615	16,079	150.2	2137	3210	3153

[a]Includes non-farm purchases of seed, fertilizer, repairs of buildings, repairs and fuel for machinery, feed, pesticides and other miscellaneous items.

[b]All farm machinery purchases, including 40 percent of the value of automobiles.

[c]Component price from Agricultural Marketing Service (120). Component prices prior to 1940 weighted by 1935-39 quantities, following 1940 by 1947-49 quantities.

[d]Component quantities from the new input series (4). Weighting procedures are similar to those in footnote c.

[e]From Agricultural Marketing Service (121). The expenditure estimated from component series for $P_O Q_O$ differs from the operating expenses (excluding labor) found in the Farm Income Situation mainly because of omission of inter-farm sales in Q_O.

estimates. For each year, the FIS estimate is slightly lower than $P_M Q_M$. But in view of the diverse means by which the latter is computed, the similarity is reassuring.

The quantity of hired labor Q_{HL} used in the simultaneous model is the farm employment estimate compiled by the AMS (Table 5). Labor price P_{HL} is the composite wage rate index for hired labor. For purposes of expenditure comparison, the quantity Q_{HL} is placed on a constant dollar basis Q'_{HL} by multiplying the employment by $1113 per worker. The expend-

Table 5. Aggregate prices, quantities and expenditures for hired labor from 1955 to 1959

	Price[a]	Quantity		Expenditure	
	P_{HL}	Q_{HL} [b]	Q'_{HL} [c]	$P_{HL}Q'_{HL}$	FIS[d]
Year	1947-49 =100	100,000 workers	$Million (1947-49)	$Million (Current)	$Million (Current)
1955	119.9	20.17	2246	2693	2736
1956	125.2	19.21	2139	2678	2733
1957	129.3	18.95	2110	2728	2785
1958	134.4	19.55	2177	2926	2878
1959	141.3	19.25	2143	3028	2929

[a]Price of hired labor P_{HL} is the index of composite wage rates compiled by Agricultural Marketing Service (118).

[b]Employment estimates compiled by the Agricultural Marketing Service (118) includes all persons doing one or more hours of work during survey week.

[c]Found by multiplying Q_{HL} by an annual wage of $1113.30 per worker.

[d]From Agricultural Marketing Service (121).

iture series obtained $P_{HL}Q'_{HL}$ compares favorably with the expenditure series although a tendency exists for $P_{HL}Q'_{HL}$ to increase, relative to FIS in later years. It is noted that $P_{HL}Q'_{HL}$ always correctly indicates the direction of change in expenditures.

Table 6 illustrates the supply quantity Q_S concept used in the simultaneous model. It measures the volume of production entering the marketing system, and is somewhat comparable to the Index of Marketings and Home Consumption. Farm output measures the farm production during the calendar year available for human consumption. The quantity supplied by the farm sector is considered to be the output less changes in farmer owned inventories. The price of the supply quantity Q_S is the index of prices received by farmers P_R. Gross income from sales and home consumption of farm products, exclusive of inter-farm sales of feed, seed and livestock, is P_RQ_S. Since these inter-farm sales are also excluded from inputs Q_O, the net income $P_RQ_S - P_OQ_O$ should be comparable to direct estimates compiled by the AMS and presented in the FIS (Table 7).

Tables 6 and 7 indicate the differences generally are small between net income estimates from variables used in the structural model and from the Farm Income Situation. The differences are eight percent or less. This does not mean that the estimates used in this study necessarily are wrong by

Table 6. Aggregate gross and net income in agriculture from 1955 to 1959 estimated from prices received by farmers, output and changes in farm stocks

	Price[a]	Quantity (Q_S)[b]			Gross income	Net income (Gross less operating expense)	
Year	P_R 1947-49 =100	Output \$Million (1947-49)	ΔS_{LF} \$Million (1947-49)	Total \$Million (1947-49)	P_RQ_S \$Million (Current)	Excluding labor[c] \$Million (Current)	Including labor[d] \$Million (Current)
1955	85.6	31,232	552.5	30,680	26,262	17,998	15,305
1956	84.9	31,591	-556.0	32,147	27,293	18,693	16,015
1957	86.7	31,505	874.6	30,630	26,556	17,801	15,073
1958	92.3	34,378	1,461.1	32,917	30,382	21,295	18,369
1959	88.6	34,860	516.1	34,344	30,429	20,814	17,786

[a]Prices received by farmers for crops and livestock (120).

[b]Output and stock of livestock and feed (S_{LF}) estimates from unpublished sources (4). Total quantity supplied for consumption, export and non-farm storage (Q_S) equals output minus changes in stocks on farms.

[c]Gross income P_RQ_S minus operating expense (P_OQ_O) and hired labor expense ($P_{HL}Q'_{HL}$). See Tables 4 and 5.

[d]Net income equals gross income excluding inter-farm sales (P_RQ_S) minus operating expenses (P_OQ_O). See Table 4 for P_OQ_O.

Table 7. Aggregate gross and net income in agriculture from 1955 to 1959 from income and expenditure estimates of the Agricultural Marketing Service[a]

	Gross income			Net income (Gross less operating expense)	
Year	Cash receipts $Million (Current)	Cons. in farm homes $Million (Current)	Total $Million (Current)	Excluding labor $Million (Current)	Including labor $Million (Current)
1955	29,785	1806	31,591	18,798	16,062
1956	31,117	1775	32,892	19,507	16,774
1957	30,840	1762	32,602	18,694	15,909
1958	34,579	1753	36,332	20,946	18,068
1959	33,827	1628	35,455	19,376	16,447

[a]From Agricultural Marketing Service, Farm Income Situation (121).

eight percent, only that slight differences in concepts, aggregation errors, etc., result in some differences. In all years the two estimates of net income depict the same direction of change. Considering the discrepancies which can arise in aggregated estimates of prices and quantities, the similarity in net income estimates is encouraging.

Conclusions

The need for estimates of the resource structure of agriculture is sufficiently pressing to justify estimation of parameters from less than perfect data. The data may be the weakest link in the estimational process, but they appear adequate to provide useful estimates of the structural parameters. Throughout the analysis, we attempt to use the most reliable data available and to aggregate with procedures that will introduce the least bias (subject to the restraints of time and research funds). But throughout the analysis, the conclusions and implications, which seem apparent from significant coefficients and meaningful economic relationships, must be tempered by the shortcomings of the data.

Time series in addition to those discussed in this chapter are used in the study. In general, these series on non-farm variables, interest rates, etc., are more reliable than the series on inputs.

Output data appear to be more precise than input data in agriculture. Series of minor agricultural products are measured with considerable accuracy. Problems of measuring inputs are many. As stated earlier, USDA personnel have done an excellent job considering the conceptual purpose of the estimates and the amount of research resources available for gathering data. The value of more refined input data is high. One wonders if the marginal research dollar will not bring a greater return extending the reliability of input data than of output data.

CHAPTER 5: THE MARKET STRUCTURE OF AGGREGATE OPERATING INPUTS AT THE FARM LEVEL

Few inputs have been more closely identified with the rising total output, output per man hour and output per unit of all resources in agriculture than have operating inputs, sometimes called working capital. Total agricultural output increased approximately 70 percent from 1926 to 1959. In 1959, production per man hour in agriculture was approximately 3.8 times as great, and per unit of all inputs was 1.6 times as great as in 1926. During the same period, of the major input categories, labor (total farm employment) declined 43 percent, land (cropland) remained nearly constant, and machinery (inventories) increased 77 percent. But annual inputs of operating items increased approximately 200 percent from 1926 to 1959. Clearly, some knowledge of the role of technological, institutional and behavioral forces determining the use of operating inputs is basic to understanding the changing structure and growing efficiency of agriculture.

Current operating inputs are here defined as purchased, non-human resources which are consumed in the production process. These non-durable resources generally are not stored on farms for extended periods, but are purchased by farmers in quantities considered to be appropriate for the needs of the forthcoming production period. Because of these properties of operating inputs, and because a given farmer's subjective estimate of acquisition cost, marginal value product and salvage cost are expected to be approximately the same value, operating inputs are the most flexible of the major farm resources. The following inputs are included in this category: (a) fertilizer and lime, (b) seed, (c) machinery supplies, including fuel, lubrication and repairs, (d) building repairs, (e) feed, (f) livestock, and (g) miscellaneous inputs such as dairy supplies, hand tools, twine, etc. Inter-farm sales of feed, seed and livestock are excluded.

In this chapter, we examine several hypotheses potentially explaining the growing use of operating inputs on farms in the United States. These hypotheses are: (a) relative prices of operating inputs have fallen -- encouraging greater agricultural production and substitution of operating inputs for other resources, (b) growing inventories of durable assets such as machinery have increased demand for operating inputs because of strong complementarity between the resources, and (c) introduction of new and improved operating inputs have increased the marginal productivity and the demand for operating inputs. This last "technological" hypothesis also includes the condition that farmers have become aware of the increased productivity and profitability of using operating inputs. Obviously, the hypotheses are not independent. The first hypothesis, a decline in the relative price, may be due to technological changes or decreasing costs in non-farm industries which supply operating items. Also, a fall in the relative price of operating inputs may encourage investment in durable assets and support the second hypothesis. Because all the above hypotheses may have influenced the purchases of operating items, no attempt is made to select one from the set. Instead, we attempt to determine the significance and relative impact of each to whatever extent research resources permit.

The procedure in this chapter is to estimate the demand for operating inputs in aggregate at the farm level by least squares and limited information statistical techniques. The supply function for operating inputs is also estimated by limited information. Several of the criteria for aggregation discussed in Chapter 4 essentially are met. That is, trends in prices of the components of operating inputs are somewhat similar. The trends in purchases of individual categories also are somewhat similar in the time period considered with the exception of building repairs. There are obvious advantages in considering economic relationships by separate components, however. In the following Chapter 6, the demand functions are estimated separately for the six categories of operating inputs listed above.

Trends in Price and Quantity Ratios

Statistical procedures such as least squares and limited information models may often be supplemented usefully by graphic techniques. To supplement the statistical estimates of substitutability and complementarity and to gain further insight into trends in resource use, Figures 1 to 4 indicate the ratio of operating input quantities and prices to related series from 1910 to 1959. Each figure contains two graphs P_0/P_1 and Q_0/Q_1 where P_0 is the price and Q_0 is the quantity of operating inputs. P_1 and Q_1 are the respective price and quantity of other major farm resources and of farm output. The substitution effect is expected to predominate in most instances, i.e. as P_0 falls relative to other prices P_1, the ratio of Q_0 to Q_1 is expected to rise. If no correspondence exists between simple price and quantity ratios, it need not necessarily imply that the resources are independent. The actual or true relationship may simply be obscured by more fundamental economic or technological forces than are considered in the two dimensional graph.

Figure 1 illustrates indices of the ratios of (a) quantities of operating inputs Q_0' to machinery inputs Q_M' (4) and (b) the price of operating inputs P_0 to the price of machinery P_M from 1910 to 1959. Machinery inputs Q_M' are valued as services required to maintain farm equipment and motor vehicles used for productive purposes. Q_M' includes depre-

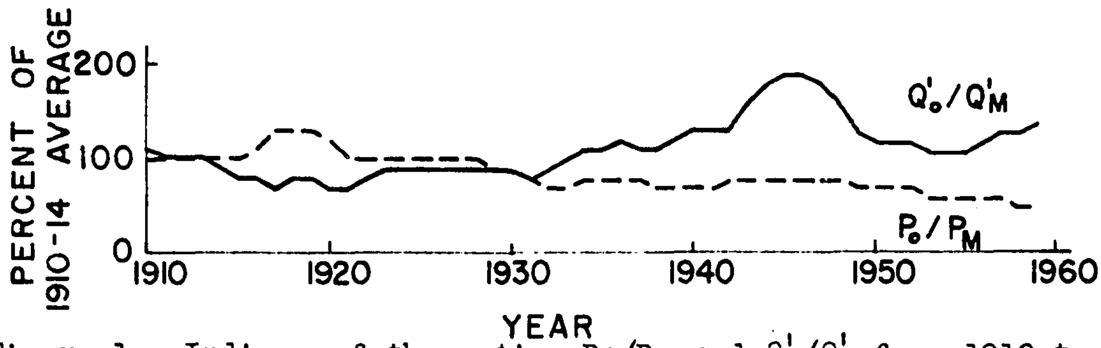

Figure 1. Indices of the ratios P_O/P_M and Q'_O/Q'_M from 1910 to 1959; 1910-14 = 100 (P_O and Q'_O are operating input price and quantity; P_M and Q'_M are all farm machinery price and quantity)

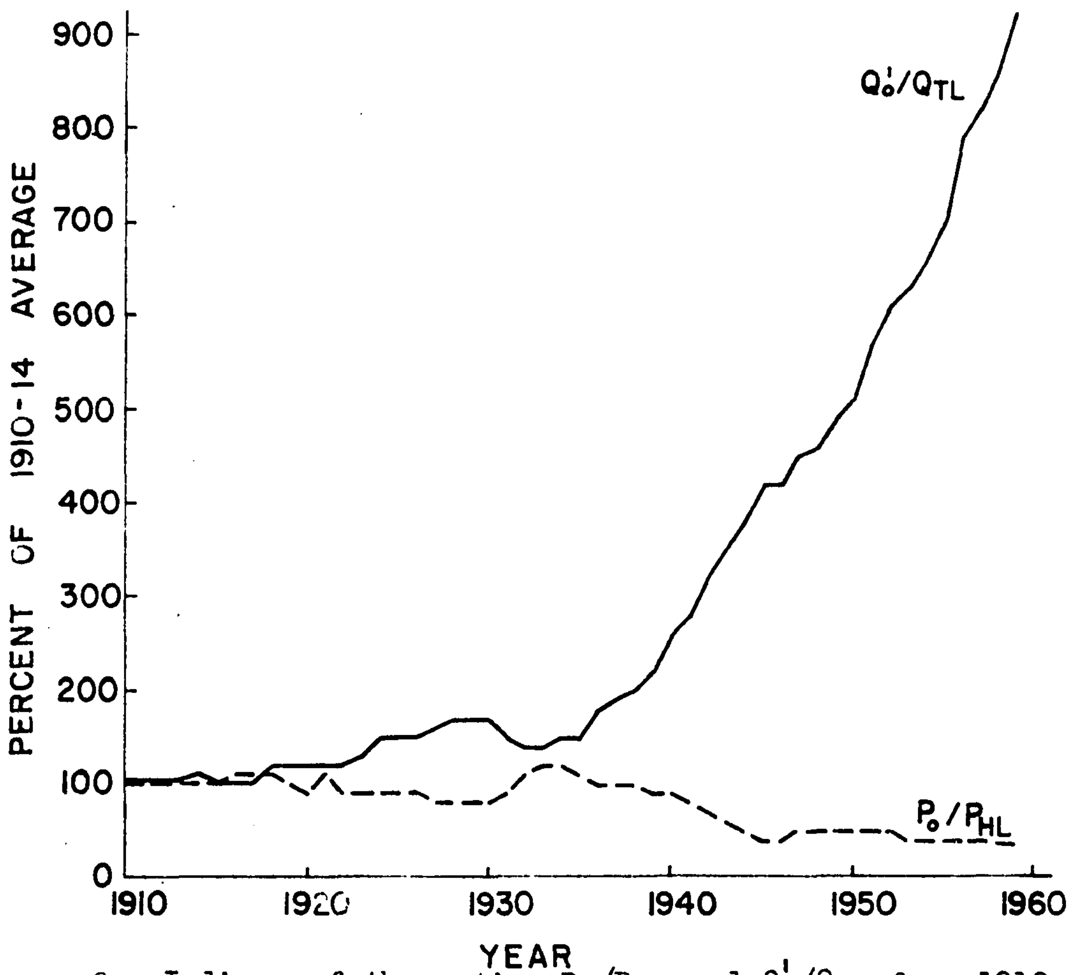

Figure 2. Indices of the ratios P_O/P_{HL} and Q'_O/Q_{TL} from 1910 to 1959; 1910-14 = 100 (P_O and Q'_O are operating input price and quantity; P_{HL} is the wage rate of hired labor and Q_{TL} is total farm employment)

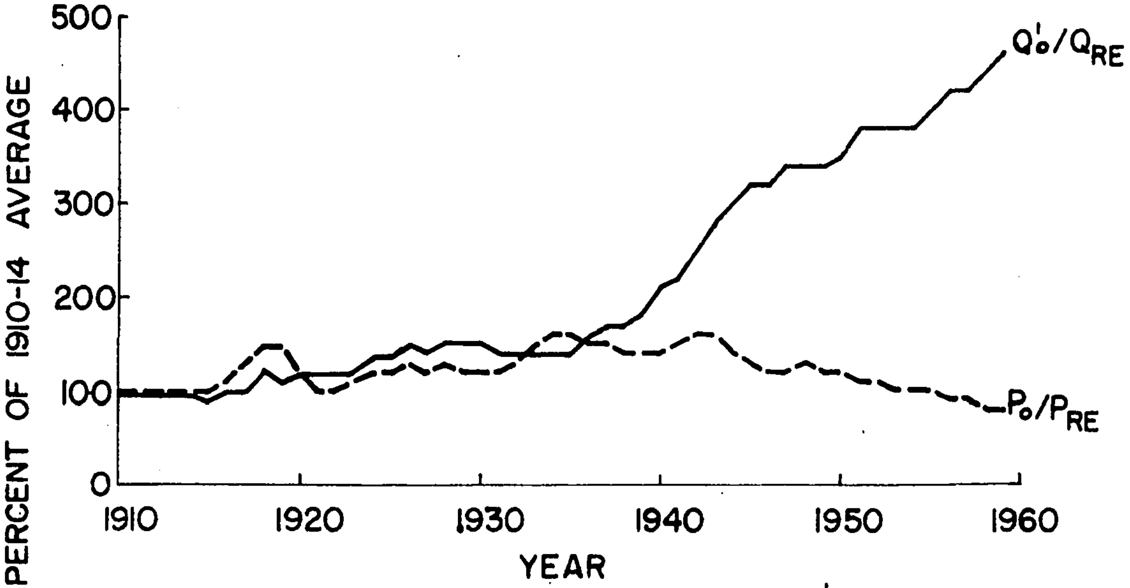

Figure 3. Indices of the ratios P_O/P_{RE} and Q_O'/Q_{RE} from 1910 to 1959; 1910-14 = 100 (P_O and Q_O' are operating input price and quantity; P_{RE} is the land price per acre, and Q_{RE} is input of real estate)

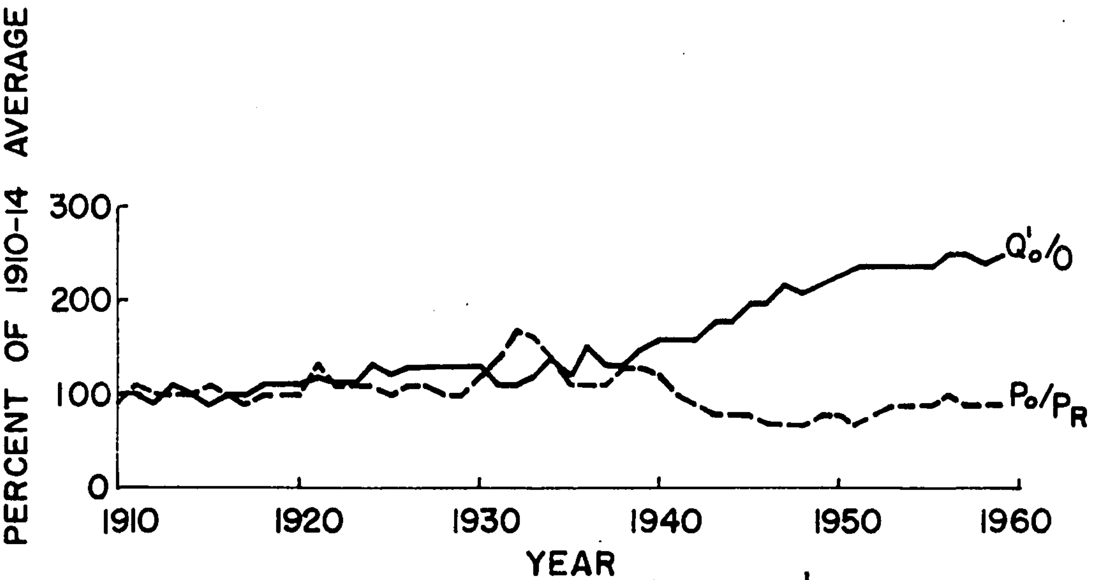

Figure 4. Indices of the ratios P_O/P_R and Q_O'/O from 1910 to 1959; 1910-14 = 100 (P_O and Q_O' are operating input price and quantity; P_R is prices received by farmers for crops and livestock, and O is total farm output)

ciation, license fees, insurance and interest on inventory. Prices of operating inputs have declined relative to machinery prices since the late 1920's. The ratio Q_O'/Q_M', however, has remained very stable, except for the war periods and the years immediately following. The increase in the ratio in 1917 to 1919 and 1942 to 1948 was due mainly to the shortage of machinery in these years. Farmers substituted operating inputs for machinery by working the old tractor longer hours, for example.

Because motor supplies in general are complements of machinery and are an important component of Q_O', the tendency exists for complementarity between Q_O' and Q_M'. Since other components of Q_O' such as weedicides may allow crop production with fewer tillage operations, there also is some tendency for substitution of Q_O' for Q_M'. From 1910 to 1959, there has been a substitution toward machinery such as tractors which use more operating inputs. The forces influencing the ratio of Q_O' to Q_M' have offset each other to a large extent, according to Figure 1.

Figure 2 indicates the indices of the ratios of: (a) Q_O' to the input of total farm labor Q_{TL}, and (b) P_O to the wage of hired labor P_{HL}. The most significant feature is the high rate of substitution of operating inputs for labor after 1935. The substitution influence was also apparent before 1935, but at a slower rate. The substitution is consistent with relative prices of the two inputs over the 50 year period.

Since 1910, a decrease in the price of operating inputs relative to labor of 60 percent has been associated with an increase in the quantity ratio of 800 percent. This suggests a gross price elasticity of substitution of approximately -13. The substitution elasticity is a gross estimate since other forces not included in Figure 2 may influence the ratio of Q_O' to Q_{TL}. That is, machinery may be the principal substitute for labor. Due to a strong complementarity between Q_O' and Q_M', the ratio of Q_O' to Q_{TL} tends to increase concurrently with increases in the ratio of Q_M' to Q_{TL}. However, Figure 2 does illustrate dramatically the tendency of purchased operating inputs to substitute for labor in a developing agriculture. Application of fertilizer, for example, permits the production of the same output with fewer labor resources.

In Figure 3, indices of the ratios of: (a) Q_O' relative to the quantity of real estate input Q_{RE} measured as interest on investment and other costs necessary to maintain the real estate investment, and (b) P_O relative to the price of real estate P_{RE}, are illustrated for the years 1910 to 1959. The tendency for Q_O' to substitute for the real estate input is prominent after the mid-1930's. Important operating inputs such as hybrid seed corn and fertilizer began to be widely accepted by farmers following the mid-1930's. These inputs allowed production of more output without a corresponding increase in the land resource. The price of operating inputs declined 20 percent relative to real estate prices over the 50 years, and the quantity ratio Q_O'/Q_{RE} increased 350 percent. The gross price substitution elasticity, -17, probably exaggerates the actual substitution rate because of confounding with technological changes.

Figure 4 depicts indices of the ratios of: (a) Q_O' to the output of crops and livestock O, and (b) P_O to prices received by farmers for crops and livestock P_R from 1910 to 1959. The ratio P_O/P_R increased during the depression years. During the remainder of the 50 years, the ratio of prices remained relatively uniform, but declined slightly since 1940. Inputs of Q_O' relative to O increased accordingly. The ratio Q_O'/O rose approximately 120 percent from 1910 to 1950. The increasing relative importance of operating inputs could result from a declining efficiency of the resource. A more logical explanation, consistent with the trends in Figures 1, 2 and 3, is that operating inputs have substituted for other inputs. The principal substitutions have been for labor and real estate as indicated by Figures 2 and 3. The substitutions have been consistent with relative price changes. Whether the entire change in the resource mix can be explained by prices or if additional forces have played an important role is explored in the following sections.

Specification of the Demand Function for Operating Inputs

The demand function for operating inputs at the farm level is specified as

$$(1)\quad Q_O = f\left[(P_O/P_R)_t,\ (P_O/P_R)_{t-1},\ (P_O/P_P')_t,\ (P_O/P_P')_{t-1},\ S_{pt},\ W_t,\ G_t,\ T\right]$$

where the demand quantity Q_O is a function of operating input prices P_O, prices received P_R, prices paid for hired labor and machinery P_P'.[1] S_p is the January 1 stock of productive

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[1]It is useful to note that the ratio form (a) below, indicated in equation 1 and used in this study, differs somewhat from the form (b) suggested by static economic theory. The two alternative least squares input demand forms with input price P_i, other input prices P_P and prices received P_R are:

$$(a)\quad Q_i = a + b\,\frac{P_i}{P_R} + c\,\frac{P_i}{P_P} + e$$

as in equation 1 above, and

$$(b)\quad Q_i' = a' + b'\,\frac{P_i}{P_R} + c'\,\frac{P_P}{P_R} + e'$$

as in the static theory model. If the data are transformed into logarithms, the price elasticities of demand E with respect to prices in the above forms (a) and (b) are:

$$E\ (P_i) = b + c \text{ in (a); } b' \text{ in (b)}$$

$$E\ (P_P) = -c \text{ in (a); } c' \text{ in (b)}$$

$$E\ (P_R) = -b \text{ in (a); } -b' - c' \text{ in (b).}$$

Since input prices P_i and P_P often are highly correlated, the matrix of price variables in form (b) may tend to be singular; the coefficients b' and c' unstable and none of the elasticities estimated accurately. In form (a), the standard error of c is likely to be large and c insignificant. This does not preclude obtaining a realistic estimate of b. Hence, there appears to be some advantage in using form (a).

assets, W is a measure of the influence of weather, G is an institutional variable indicating the existence of acreage controls and price supports, and T is time. In the model t refers to the current years, t-1 to the past year.

Equation 1 is a single equation model of demand and assumes a monocausal structure. The argument for the monocausal structure is based on the assumed nature of the supply of operating inputs. Short run changes in Q_O are not expected to influence P_O, P_R or other input prices to an appreciable extent. It is also assumed that purchases of Q_O have little influence on the stock of productive assets S_p in the short run. The general assumption is that the explanatory variables influence Q_O but are not influenced by it in the short run. Because the logic and empirical data supporting this assumption are not completely adequate, it is desirable also to estimate the demand for operating inputs as part of an interdependent economic structure. The simultaneous model of demand for operating inputs was presented in equation 25, Chapter 2. The specification of variables is similar except that the price ratio form is used in equation 1, and prices of labor and machinery are included separately in the simultaneous model.

A more complete demand specification might include: (a) a farm income variable, (b) a farm size variable, and (c) several categories of prices received and prices paid by farmers. Prices rather than income appears to be the relevant farmer decision variable in the demand function for operating inputs. Furthermore, income tends to be a function of prices, weather and technology variables already specified.

As farm size expands, a tendency exists to substitute additional motor supplies, fertilizer and other operating inputs for labor. Unfortunately, the very high correlation between farm size (cropland acres per farm) and the stock of productive assets S_p precludes including both variables in the statistical demand function. The coefficient of S_p must be interpreted as reflecting the influence of farm size as well as other scale effects.

It would be desirable to specify several categories of prices received for products and prices paid for inputs by farmers. High intercorrelations among prices over time prohibit such refinements. In fact, the high intercorrelations among input prices required the exclusion of the current year price ratio $(P_O/P_P')_t$. The coefficient of the included past year ratio tends to reflect both current and past influences of P_O/P_P' on Q_O because of the high correlation in the time series.

The process by which farmers formulate price expectations and adjust input purchases to uncertain conditions may result in a demand pattern discussed extensively in the literature on the theory of distributed lags (85, 98, 99). Because of the time required for production, farmers who wish to maximize profit must base input purchases on expected prices. The expected prices are formulated from knowledge of past prices. It may be argued that prices lagged no more than one or two years provide a satisfactory estimate of farmers' price expectations in operating input demand functions. Input prices are determined primarily by slowly changing variables such as the non-farm wage rate. Hence, prices of non-farm produced inputs display very small annual variation and are free of cyclical fluctuations so characteristic of many farm product prices. Since input prices are known with considerable certainty when production plans are made, the principal expectation variable is output price. Since the non-durable production inputs are consumed in the forthcoming production period, their expected profitability is not a function of prices in several future production periods. It seems reasonable to assume that farmer decisions regarding the immediate future are based on the immediate past. Thus, inclusion of product price variables for only one or two past production periods appears adequate.

A second source of a distributed lag model of demand is a lagged adjustment to the equilibrium level of input, given prices and other predetermined variables. That is, a farmer who is subjectively certain of prices may adjust slowly to a profit maximizing level of resource use because of inertia of past decisions, institutional restraints, large investment requirements or indivisibility of inputs. Properties discussed previously of operating inputs permit flexibility in their use. Ease of adjustment to desired input levels mitigates to some degree the need for an adjustment lag in the demand function. It is hypothesized that use of operating inputs has become increasingly more profitable because of technological changes, greater amounts of durable assets and declining real price P_0. The most logical source of the lagged adjustment to the desired Q_0 arises from incomplete knowledge or skepticism by farmers of the increased profitability, convenience and other advantages of using more Q_0. An econometric model embodying this adjustment concept is found in Chapter 7 (model F) and is used in the quantitative applications in Chapters 5 and 6.

The inclusion of the productive assets S_p in the demand function adjusts for changes in scale of the farm plant. Hence, equation 1 is the short run demand for Q_0, i.e., the demand for operating inputs given the plant size. The influence of S_p on the demand quantity depends on the interaction between Q_0 and S_p and on the fixed level of productive assets. Higher levels of S_p might be expected to increase marginal productivity (and demand) for Q_0 until the stage of diminishing total product to S_p is reached. Since productive assets in agriculture probably are not in this stage of production, a positive sign on the coefficient of S_p in equation 1 is anticipated.

In the long run, plant size becomes a function of depreciation D, financial capabilities E, farm income Y and other variables summarized by the variable X. The general form of investment function, omitting time subscripts is

(2) $$S_p = f\ (Y,\ E,\ D,\ X).$$

The recursive nature of the demand process allows substitution of the right side of equation 2 into equation 1 to form the long run demand function 3. Ignoring time subscripts, long run demand

(3) $$Q_0 = f\ (P,\ G,\ W,\ T,\ Y,\ E,\ D,\ X)$$

for Q_0 becomes a function of all relevant prices P and other variables discussed previously.

Government programs such as acreage controls and price supports may affect demand for Q_0. There are indications from historic data that acreage controls encourage substitution of Q_0 for land in production. An institutional variable G is specified in the demand function to represent the influence of government policies in the demand function.

Bad weather at planting time may cut crop acreage and reduce demand for seed, fertilizer and machinery operating supplies. The weather variable W is specified in the demand function to measure shifts in demand caused by weather.

Demand for Operating Inputs Estimated by Least Squares

Economic theory, introspection and logic do not dictate an exact functional form of input demand. The appropriateness of the distributed lag or other models cannot be determined solely on a priori considerations. The procedure in this section is to estimate (a) conventional models with short run lags and (b) distributed lag models of the Koyck-Nerlove type. Furthermore, we present functions with different sets of explanatory variables. The procedure is to begin with the model as completely specified as practical limitations of data availability and estimational procedures permit. Variables considered inappropriate because of low significance and high intercorrelation with other variables are deleted in subsequent regressions. All equations are estimated in original data and in data transformed to logarithms. Since the two dummy variables for slowly changing effects on the demand, time T and government policies G, are not well suited for logarithmic transformation, equations containing both variables are estimated in original data only. Finally, if the Durbin-Watson test indicates probable autocorrelation in residuals of an equation which is of particular interest, the equation is also run in first differences.

The alternative functional forms listed above are presented to clarify and extend knowledge of the "true" function. Presentation of several forms is also intended to demonstrate the effects of alternative specifications and transformations; and to create a "desirable" degree of skepticism about estimation procedures. There often is a tendency to place too much reliance on a significant coefficient in one "good" equation.

The variables

The variables indicated in Table 1 are defined as follows:

Q_{Ot} The dependent variable is a weighted national aggregate of fertilizer, seed, motor supplies, building repairs, feed, livestock and miscellaneous inputs (4). Quantities are aggregated by 1935-39 prices prior to 1940, and by 1947-49 prices after 1940. Overlapping values for 1940 are used to value the final aggregated series in 1947-49 million dollars. Inter-farm sales are excluded, hence only a small portion of total livestock purchases are included.

$(P_O/P_R)_t$ The current year index of the ratio of operating input prices to prices received by farmers for crops and livestock (120). The past year index is also included. The procedure for weighting components of P_O is given in Chapter 4.

$(P_O/P_P')_{t-1}$ The past year index of the ratio of operating input prices to prices paid by farmers for machinery and hired labor (120).

S_{pt} The stock of productive assets on January 1 of the current year (4, 123). The variable includes real estate, machinery, livestock, feed and cash inventories held for productive purposes. The variable is given in billions of 1947-49 dollars.

G_t An index of the role of government policies on input purchases. Years when acreage allotments or production controls are in force are given the value -1. Years when farm prices are supported are assigned the value +1. If supports are fixed, an additional +1 is added. These values are summed to form the index G (3, 34).

W_t Stalling's index of the influence of weather on farm output in the current year (108). Indices for 1958 and 1959 are not computed by Stalling, but are constructed from an index of deviations from a linear trend of crop yields (124).

T Time, an index composed of the last two digits of the current year.

All price indices are adjusted to a 1947-49 base (1947-49=100). The variables are annual data from 1926 to 1959 omitting 1942 to 1945. The period is chosen as a compromise between: (a) a period sufficiently long to allow variation in the variables and to provide sufficient degrees of freedom, and (b) a period short enough to permit reasonable accommodation of structural changes in the empirical model. The war period is considered too great a structural change to incorporate in the empirical function. Although prices and other variables indicated farmers should increase purchases to maximize profit, they were unable to do so because operating inputs were not available in sufficient quantities. The inclusion of a longer time series would introduce more error because data are less accurate for the early years. For these reasons and because research resources are limited, no attempt was made to estimate demand functions for years prior to 1926.

The estimated demand equations

Single equation least squares estimates of the demand for Q_0 as a function of price and other variables are presented in Table 1. The seven independent variables in equation 4 "explain" over 99 percent of the annual variation about the mean of Q_0.[2] The unusually high R^2 is caused by the tendency

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[2]The term "explain" is a somewhat inexact generalization of the statistical multiple coefficient of determination R^2. R^2 is the ratio of the sum of squares of the estimated values of the dependent variable to the sum of squares of the actual values of the dependent variable. The R^2 may also be considered the square of the multiple correlation coefficient R between the dependent variable and a linear function of the independent variables. The R^2 may be made equal to one by including one less explanatory variables than the number of observations. The adjusted multiple coefficient of determination $\bar{R}^2$ is corrected for the influence of the number of explanatory variables.

Table 1. Demand functions for operating inputs Q_O estimated by least squares 1942 to 1945; coefficients, standard errors (in parenthesis) and re

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_O/P_R t	P_O/P_R t-1	P_O/P_P' t	P_O/P_P' t-1
4-0	0.997	1.42	-5939.07	-7.64	-1.89		-10.32
	0.996			(1.94)	(2.19)		(4.89)
5-0	0.996	1.21	-4557.10	-7.61	-2.77		-13.93
	0.995			(1.96)	(2.09)		(3.94)
5-L	0.99	0.73	2.25	-0.29	-0.23		-0.17
	0.99			(0.10)	(0.10)		(0.19)
5-F	0.51	1.51	--[d]	-5.87	-2.35		-13.65
	0.39			(1.98)	(2.02)		(6.39)
6-0	0.99	1.04	-4511.47		-9.06		-13.41
	0.99				(1.66)		(4.95)
6-L	0.99	0.80	2.73		-0.465		-0.24
	0.99				(0.076)		(0.21)
6-F	0.31	1.65	--[d]		-4.79		-9.95
	0.19				(2.14)		(7.25)
7-0	0.997	1.60	-488.55	-4.58		3.16	
	0.997			(1.13)		(4.30)	
7-L	0.996	1.49	0.75	-0.237		0.17	
	0.996			(0.041)		(0.15)	
8-0	0.997	1.60	230.18	-4.28			
	0.997			(1.05)			
8-L	0.996	1.40	1.39	-0.233			
	0.996			(0.041)			

[a]Sources and composition of the dependent variable Q_O and the indicated ir

[b]Equations are estimated in the transformations indicated: original value equations), and first differences of original values F.

[c]The Durbin-Watson autocorrelation statistic d'.

[d]The intercept or constant coefficient in the first difference equation is equations. The standard error of the coefficient was not computed.

y least squares with annual data from 1926 to 1959, omitting
enthesis) and related statistics are included[a]

P_O/P_P' t	P_O/P_P' t-1	S_p t	G t	W t	T	Q_O t-1
	-10.32	117.98	6.47	6.57	53.81	
	(4.89)	(9.58)	(5.30)	(2.64)	(14.60)	
	-13.93	113.03		6.37	46.78	
	(3.94)	(8.77)		(2.67)	(13.55)	
	-0.17	1.18		0.115	0.0086	
	(0.19)	(0.31)		(0.079)	(0.0018)	
	-13.65	72.81		1.89	82.82	
	(6.39)	(27.15)		(2.05)	--[d]	
	-13.41	105.93		5.23	57.56	
	(4.95)	(10.80)		(3.33)	(16.69)	
	-0.24	0.94		0.103	0.0091	
	(0.21)	(0.34)		(0.090)	(0.0021)	
	-9.95	61.40		1.21	98.86	
	(7.25)	(31.11)		(2.35)	--[d]	
3.16					34.65	0.879
(4.30)					(11.87)	(0.054)
0.17					0.0050	0.780
(0.15)					(0.0012)	(0.083)
					28.74	0.857
					(8.63)	(0.045)
					0.00417	0.711
					(0.00091)	(0.056)

the indicated independent variables are discussed in the text.

original values O, logarithms L (T is in original values in L

ence equation is comparable to the coefficient of T in the O and L
ted.

for aggregation to average out the error in Q_0. Also, a large proportion of the variability is due to the highly predictable trend variables S_p and T. The R^2 falls considerably when the functions are estimated in first differences of original values in equations 5-F and 6-F.

The coefficient of the institutional variable G is non-significant in equation 4-0, and is deleted to form equation 5. Our failure to reject the null hypothesis that the coefficient of G is not different from zero, does not necessarily mean that government programs do not influence demand for Q_0. But there exists a high probability that the variable G used to represent that effect, has no influence on Q_0 in equation 4-0.

The Durbin-Watson statistic d' is included for each equation in Table 1 to test the null hypothesis that the true residuals are uncorrelated through time. Values of d' near 2.0 indicate that the residuals are distributed randomly, i.e., we do not reject the null hypothesis that the residuals are uncorrelated through time. Values of d' less than two and approaching zero indicate an increasing degree of positive autocorrelation. Values of d' greater than two and approaching four indicate an increasing degree of negative autocorrelation. It must be remembered that d' is a sample statistic and is subject to sampling error.[3]

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[3]For a more detailed discussion of autocorrelation, see Chapter 3 and other references (continued on next page)

Since a test of the null hypothesis that the true residuals are uncorrelated is inconclusive in equation 5-O and is rejected in equation 5-L, the equation is estimated in first differences of original values. After the first difference transformation, the test for autocorrelation in equation 5-F is inconclusive.

The signs of the coefficients in all transformations of equation 5 are consistent with a priori considerations from economic theory. The magnitudes of the coefficients differ among transformations, however. The influence of $(P_O/P_R)_{t-1}$ appears to be stronger and the influence of $(P_O/P_P')_{t-1}$ weaker in equation 5-L than in equations 5-O and 5-F.

Equation 5 possesses certain intuitive appeal because some components of Q_O are expected to be influenced by current as well as by past prices. For predictive purposes, current prices may not be known and it is necessary to base predictions on past values of the independent variables. It may be argued that the nature of the least squares algorithm will result in a more efficient, though perhaps slightly biased estimate of Q_O, from equation 6 ($(P_O/P_R)_t$ omitted) than from equation 5 if only past values of the explanatory variables are known. It is interesting to note that the coefficient of

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(footnote continued from previous page) (40, 41). Probability limits of the d' distribution are found in Friedman and Foote (38) and Durbin and Watson (29).

lagged price P_O/P_R in equation 6 absorbs the influence of current price. For example, the coefficient of $(P_O/P_R)_{t-1}$ in equation 6-0 is -9.1 and the sum of the coefficients of $(P_O/P_R)_t$ and $(P_O/P_R)_{t-1}$ in equation 5-0 is -7.61 plus -2.77, or -10.4. Thus, failure to specify the current price variable in time series analysis when it is important may not seriously bias the estimate of total short run response to price if current and lagged values are sufficiently correlated. It would be wrong, however, to infer the entire price response to the single lagged price variable. Equation 6 also explains a large portion of the variance in Q_O and is a useful predictive equation from a positivistic standpoint.

On the basis of equations 4, 5 and 6, it may be argued that the Koyck-Nerlove distributed lag model is not appropriate. A large proportion of the variation about the mean of Q_O is "removed" by the current and past year explanatory variables in equations 4, 5 and 6 (untransformed data). It is also a fact that the current and past values of Q_O display a high serial correlation. The implication is that from a statistical standpoint, the lagged quantity is likely to be highly correlated with a linear combination of the explanatory variables. In such instances, the matrix of predetermined variables tends to be singular and the statistical "law" is unable to differentiate the influence of individual predetermined variables. The coefficients tend to be unstable and statistical inference becomes difficult or impossible. The interpretation from an economic standpoint is that the influence of past values of explanatory variables on current quantity Q_{0t} represented in the demand equation by Q_{0t-1} is expected to be small. That is, the current demand quantity essentially is determined by exogenous variables of the current and past year. Partially as an empirical test of this hypothesis, equations 6-O and 6-L were estimated with the addition of the predetermined variable Q_{0t-1}. In the resulting equations (not included in Table 1) the coefficients of Q_{0t-1} were highly insignificant. The implication is that farmers adjust operating input purchases to prices, scale of plant and technology in the short run. The adjustment coefficient is unitary according to these results (cf. model F, Chapter 7).

This conclusion may be too restrictive, however. Equations 6 and 7 indicate that if S_p is excluded, the coefficient of lagged quantity in the adjustment equations becomes highly significant. If it is not necessary to include S_p in the demand function, i.e. its significant coefficient reflects the lagged adjustment and technology effects that logically belong with variables T and Q_{0t-1}, then equations 6 and 7 are appropriate. Furthermore, the time variable could be removed, and the price and lagged quantities could explain current demand for Q_0 very well. The implication would be that the increase in demand quantity would be entirely attributed to lagged adjustment to the secular price decline. The conclusion one must draw from the above statements is that the results may be consistent with several hypotheses. It is not possible to adequately distinguish the influence of adjustment to price changes, technology and scale of plant on purchases of Q_O. Variables reflecting these influences are too highly correlated through time and are subject to large error. The sample size is simply not large enough to place a great deal of confidence in estimates of their individual effects.

With these limitations in mind, it seems appropriate to consider two alternative methods of estimating long run demand for operating inputs. The first approach is to omit S_p and include Q_{Ot-1} as an indication of long run influences. From the resulting distributed lag equations such as 7 and 8, estimates of long and short run elasticities, and adjustment rates can be found.

A second approach is to consider the long run demand for Q_O as a recursive process. Empirical results indicate there are no long run influences of prices on Q_O, given the scale of plant indicated by S_p and technology indicated by T. But in the long run, prices influence plant size. In Chapter 9, investment S_p is estimated as a function of farm income Y_F. Investment equation 23, Chapter 9, estimated with original annual data from 1913 to 1959, omitting 1942 to 1947, may be written as

(9) $S_{pt} = K + 0.00017\ Y_{Ft-1} + 0.00011\ Y_{Ft-2} + 0.000056\ Y_{Ft-3}$

where K represents the influence of time, weather and carry-over of stock. Y_F is net income in millions of 1947-49 dollars. Net income is translated to prices by definitional equation 6, Appendix B, which may be specified as

(10) $$Y_{Ft} = K' + 209.46\ (P_R/P_P)_t$$

where P_R is prices received by farmers and P_P is prices paid by farmers for items used in production, including interest, taxes and wage rates. Equation 10 was estimated by least squares with annual data from 1910 to 1959, omitting 1942-45, but the variable P_R/P_P is the index of the ratio of P_R to P_P (1947-49=100) from 1946 to 1959 only. The coefficient indicates that from 1946 to 1959, an increase of the parity index by one unit increased net farm income an average of slightly over 200 million 1947-49 dollars. K' represents other influences such as weather, technology, etc. on farm income. The right side of equation 10 is substituted into equation 9 to define investment in terms of prices. This expression is then inserted into equation 5 to form the approximate "long run" demand function 11.

(11) $$\begin{aligned} Q_O = K'' &- 7.61(P_O/P_R)_t - 2.77(P_O/P_R)_{t-1} \\ &- 13.93(P_O/P_P')_{t-1} + 4.01(P_R/P_P)_{t-1} \\ &+ 2.67(P_R/P_P)_{t-2} + 1.33(P_R/P_P)_{t-3}\ . \end{aligned}$$

K" is the sum of the influences of weather, technology and errors in predicting Q_O. Equation 11 is included to demonstrate the methodology for deriving long run demand. Unfortunately, equation 11 is still not the full long run demand function for operating inputs, but further lags would make the equation cumbersome. The investment function 9 contains provisions for a lagged adjustment to the desired level of stock (cf. models I and J, Chapter 7). The nature of this lagged adjustment is not discussed in this chapter, but provision is made for the total long run response of investment stock to prices in the later sections on price elasticities.

Demand for Operating Inputs Estimated by Limited Information

The demand for Q_O is also estimated in a relationship in which prices and quantities of farm products and resources, and farm numbers are determined simultaneously. The limited information estimates of demand for operating inputs, computed with national aggregates of annual data from 1926 to 1959, excluding 1942 to 1945, are included in equation 12.

$$(12)\quad Q_O = -14 - \underset{[-2.23]}{110P_{Ot}} + \underset{[0.51]}{25P_{Mt}} - \underset{[-0.63]}{41P_{HLt}} + \underset{[1.12]}{112P_{Rt}} - \underset{[-0.56]}{47N_t}$$

$$- \underset{[-0.078]}{2.9(P_O/P_R)_{t-1}} + \underset{[3.07]}{171S_{pt}} + \underset{[0.0075]}{7.5G_t} + \underset{[0.074]}{7.4W_t}$$

$$- 0.40C_t \; .$$

P_M is farm machinery price, P_{HL} is the wage rate of hired labor, N is farm numbers and C is a structural variable with values of zero in prewar years, 100 in postwar years. Prices are deflated by the general price deflator of the gross national product (1947-49=100). The first six variables are endogenous, the remaining five are predetermined. Other variables are explained earlier in the chapter. Elasticities are included in brackets below the coefficients. Standard errors were not computed.

With two exceptions, the signs of the coefficients are consistent with economic theory and with the results of past empirical studies. The equation indicates that the demand quantity Q_O increases as farm numbers decrease. Because total acreage is quite stable, the implication is that an increase in farm size is accompanied by an increase in demand for current operating inputs. The result may be due to the substitution of operating inputs for hired labor and machinery in the short run as additional land is purchased. A farmer who expands his operation by buying a contiguous unit of land, tends to farm it with little additional machinery in the short run. In the long run, as his financial condition improves and his desire to reduce family labor requirements increases, he will purchase additional large, more efficient machines.

Equation 12 approximately is homogeneous of degree zero with respect to prices. The equation is consistent with equations 3-0 and 4-0 in indicating the importance of current prices in the demand function. The signs of the P_O and P_R coefficients are as anticipated, but the magnitudes indicated by the bracketed elasticities appear to be unusually large. The unusual magnitudes may be due to specification bias or to certain properties of limited information estimators discussed in Chapter 3. The coefficients of P_M and P_{HL} indicate that operating inputs are short run substitutes for machinery and complements of hired labor. The opposite relationship might have been expected, but a priori evidence on the nature of short run substitutions is meager.

The coefficients of S_p, W and G are somewhat similar to those in equation 5 and are not discussed further. The coefficient of the structural variable C is very small, indicating that there has been little change in the demand structure not attributable to the other variables in equation 12. C rather than a linear time trend T is used in equation 12 to reduce the intercorrelation among predetermined variables.

Price Elasticities of Demand

In the discussion of price elasticities, particular emphasis is placed on the short run demand equation 5 and the long run equation 11 derived from it. We first consider the elasticity with respect to P_O. Since some instability exists in the coefficients of the current and past year prices, the responses for these years are added and referred to as "short run" price elasticity. The short run price elasticity of demand for Q_O with respect to P_O/P_R is -0.28, -0.52 and -0.22 computed from equations 5-O, 5-L and 5-F, respectively. The elasticity of Q_O with respect to $P_O/P_P^{'}$ is -0.36 from equation 5-O; -0.17 from equation 5-L, and -0.35 from equation 5-F. Thus, the total short run elasticity with respect to P_O is -0.64, -0.69 and -0.57 from the respective transformations. The implication is that a decrease of one percent in the price of operating items is expected to increase purchases approximately 0.6 percent in the short run. The operating input price P_O does not explicitly occur in variables beyond the short run according to the long run equation 11. A literal interpretation is that -0.6 is also the long run elasticity of Q_O with respect to P_O. P_O is a component of P_P, however. Therefore, the long run elasticity is somewhat greater than -0.6 due to the long run influence of P_P on Q_O through the productive assets variable.

It is interesting to compare the estimate of the demand elasticity -0.6 computed from equation 5 with the elasticities obtained from other estimational techniques: (a) a weighted average of the elasticities computed from the six demand equations for components of Q_O estimated in the following chapter, (b) from the Koyck-Nerlove equation 8, (c) from an average production function for U.S. agriculture illustrated in equation 1, Appendix A and (d) from the limited information demand equation 12. The elasticity with respect to P_O estimated as a weighted average from the six components of Q_O discussed in the following chapter is -0.66 and agrees closely with the single aggregate estimate from equation 5.[4] The estimate of elasticity from the distributed lag equation 8-L is -0.2 in the short run, -0.8 in the long run. This result is not necessarily in conflict with the -0.6 estimate from equation 5. The lower estimate -0.2 is for the current year only and is expected to be small. The larger estimate -0.8 is for the long run, and if the component of P_O in P_P were included in the estimate from equation 5, the elasticity estimates for the long run from equations 5 and 8 might be very similar. The elasticity of Q_O with respect to P_O computed from the limited information demand equation 12 is -2.3 and from the average production function (equation 1, Appendix A) is -1.4.[5] These estimates are unusually large. Because of

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[4]The weighted estimate of short run demand elasticity -0.66 computed from individual demand equations in Chapter 6 and the estimate 0.6 from equation 5 differ somewhat in concept. First, inter-farm sales are exluded in Q_O but are included in the individual quantities (dependent variables) used in Chapter 6. However, the weights for the component demand elasticities are averages of constant dollar purchases from 1926 to 1959, omitting the war years, and excluding inter-farm sales. Second, the livestock component is included in Q_O but not in the component estimates in Chapter 6.

[5]The short run demand elasticity computed from the logarithm production function in terms of the production elasticity b for Q_O is 1/b-1. From equation 1, Appendix A, b=0.27, and the short run demand elasticity therefore is -1.4.

certain characteristics of logarithm production functions discussed in another publication (115), the estimate -1.4 probably is too large. The estimate from the limited information technique also may be too large because of specification errors or properties of the estimational technique. On the basis of statistical properties of the functions and past empirical studies, the results from the least squares demand equations in Table 1 appear to be most realistic.

Thus far we have discussed the elasticity with respect to P_O. From a policy standpoint and for other reasons, the elasticity with respect to P_R is very important. The elasticity with respect to P_R computed from equation 5-O is 0.28, from equation 8-L is 0.22 in the short run. In the long run, an increase in P_R also increases Q_O through the investment process. Equation 11 indicates that after three or four years, a one percent increase in P_R increases Q_O about 0.13 percent through S_p alone. The total intermediate run (three or four years) elasticity with respect to P_R approximately is 0.28 plus 0.13, or 0.41. After several years, a one percent increase in P_R may increase S_p as much as one percent. Since a one percent increase in S_p tends to increase Q_O approximately two percent according to equation 5, the long run elasticity of Q_O with respect to P_R potentially is more than 2.0.[6] Purchases of operating inputs can be very responsive

[6]Elasticity derived from equations estimated in original observations are not strictly (continued on next page)

to prices received by farmers in the very long run.

Shifts in Demand

As mentioned previously, hypotheses which potentially explain the increased use of operating inputs from 1926 to 1959 are: (a) falling relative prices of operating inputs, (b) increases in the level of durable assets accompanied by a strong complementarity between durable assets and operating inputs, (c) technological innovations, resulting in new inputs and increasing marginal productivities of existing inputs. Also included in the final hypothesis are increases in knowledge by farmers of the changing technological structure.

The first hypothesis is approximated by the variables P_O/P_R and P_O/P_P', the second by S_p and the third by T. The hypotheses are not mutually exclusive. In fact, equation 6 indicates each has been a significant component of the demand function from 1926 to 1959. The relative influence of each of

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(footnote continued from previous page) additive. That is, it is not completely accurate to multiply the elasticity of S_p with respect to P_R times the elasticity of Q_O with respect to S_p to find the elasticity of Q_O with respect to P_R. The correct procedure is to compute the coefficient of the influence of P_R on Q_O by the recursive process indicated in equation 11. This latter method is laborious, and it is sometimes more desirable from a computational and expository standpoint simply to multiply elasticities. Elasticities often are multiplied in this study for this reason, and in most instances the error is very small in relation to other possible sources of discrepancies.

the explanatory variables in equation 6-0 on the demand quantity is evidenced by the standard partial regression coefficients: -0.13 for $(P_O/P_R)_{t-1}$, -0.22 for $(P_O/P_P)_{t-1}$, 0.03 for W_t, 0.42 for S_p and 0.27 for T.[7] The results indicate that weather exerts relatively little influence on Q_O. The most important relative effect arises from S_p according to equation 6-0.

Despite the statistical significance and relative magnitudes of the coefficients, the importance of a given variable in explaining the 216 percent increase in purchases of Q_O from 1926 to 1959 also depends on trends in the variables. P_O/P_R and P_O/P_P' dropped 17 and 60 percent respectively from 1926 to 1959. Equation 5-0 indicates that the falling real price of operating inputs explained about one third of the total

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[7]The standard partial regression coefficient b' is computed as

(a) $$b_i' = b_i \sqrt{\frac{\Sigma x_i^2}{\Sigma y^2}}$$

where b_i is the multiple correlation coefficient, Σx_i^2 is the corrected sum of squares for independent variable X_i and Σy^2 is the corrected sum of squares for the dependent variable. The standard partial regression coefficients are corrected for the estimated differences in variance and are intended to reflect the relative influence of the independent variables on Y. They are somewhat comparable to the usual estimates of elasticities E_i, of Y with respect to X_i, computed at the means, i.e.

(b) $$E_i = b_i \frac{\bar{X}_i}{\bar{Y}} .$$

The elasticities are corrected by the ratio of the means; standard partial regressions by the square root of the ratio of estimated variances.

increase in purchases of Q_0 in the 33 year period. That is, if the short run price variables in equation 5-0 are set at the 1959 level and other variables are left at the 1926 level, the predicted value of Q_0 is 67 percent above the 1926 predicted value.[8] The stock of productive assets rose 31 percent from 1926 to 1959. Ceteris paribus, the predicted demand for Q_0 would have been 112 percent greater in 1959 than in 1926 because of the complementarity with S_p. If the time variable is set at the 1959 value and other variables are at the 1926 values, equation 5-0 indicates that Q_0 would have been 61 percent greater. The three hypotheses suggest a 240 percent increase; hence "overexplain" the actual 216 percent increase in purchases of Q_0. The discrepancy arises from statistical error.

The results seem to indicate that the major source of

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[8]The estimated demand equation may be used as an approximate device to determine the sources of increasing demand from year 1 to year k. A least squares demand equation with time subscripts for year i is of the form

(a) $Q_i = a + b\ P_i + C\ T_i \qquad (i = 1,2,\ldots n)$

where Q is predicted quantity, P is price and T is the demand shifter. Assuming the error in prediction is negligible, then the percentage change in Q from year 1 to year k due to P is

(b) $$\%\ \text{change} = \frac{b\ (P_k - P_1)}{Q_1} \cdot 100$$

and due to T is

(c) $$\%\ \text{change} = \frac{c\ (T_k - T_1)}{Q_1} \cdot 100\ .$$

increase in demand for operating inputs arises from the growth of productive assets. This conclusion must be severely qualified. S_p is one of several trend variables moving similarly through time. Because of the high correlation between these trend variables reflecting the growth of productive assets, technological conditions, knowledge, managerial ability and long run price effects, it is not possible to estimate the relative influence of each on Q_0 from time series. A more realistic statement is that about one-third of the total increase in purchases of Q_0 from 1926 to 1959 is due to short run price influences. The remaining two-thirds of the total increase is ascribed to technological and managerial influences, complementarity with the growing agricultural plant, and to long term price effects. The variables other than short run prices have moved similarly through time and have not registered observable individual effects. The increase in demand substantially can be "explained" in terms of any one of these hypotheses by inserting the "proper" trend variable in the demand function.

Trends and Projections

Figure 5 depicts the trend in purchases of Q_0 from 1926 to 1959. Purchases fell sharply in the depression years of the early 1930's, but recovered quickly. Thereafter, inputs of Q_0 tended to increase at a uniform rate except for interruptions in 1938 and 1953. The trend in the postwar era has

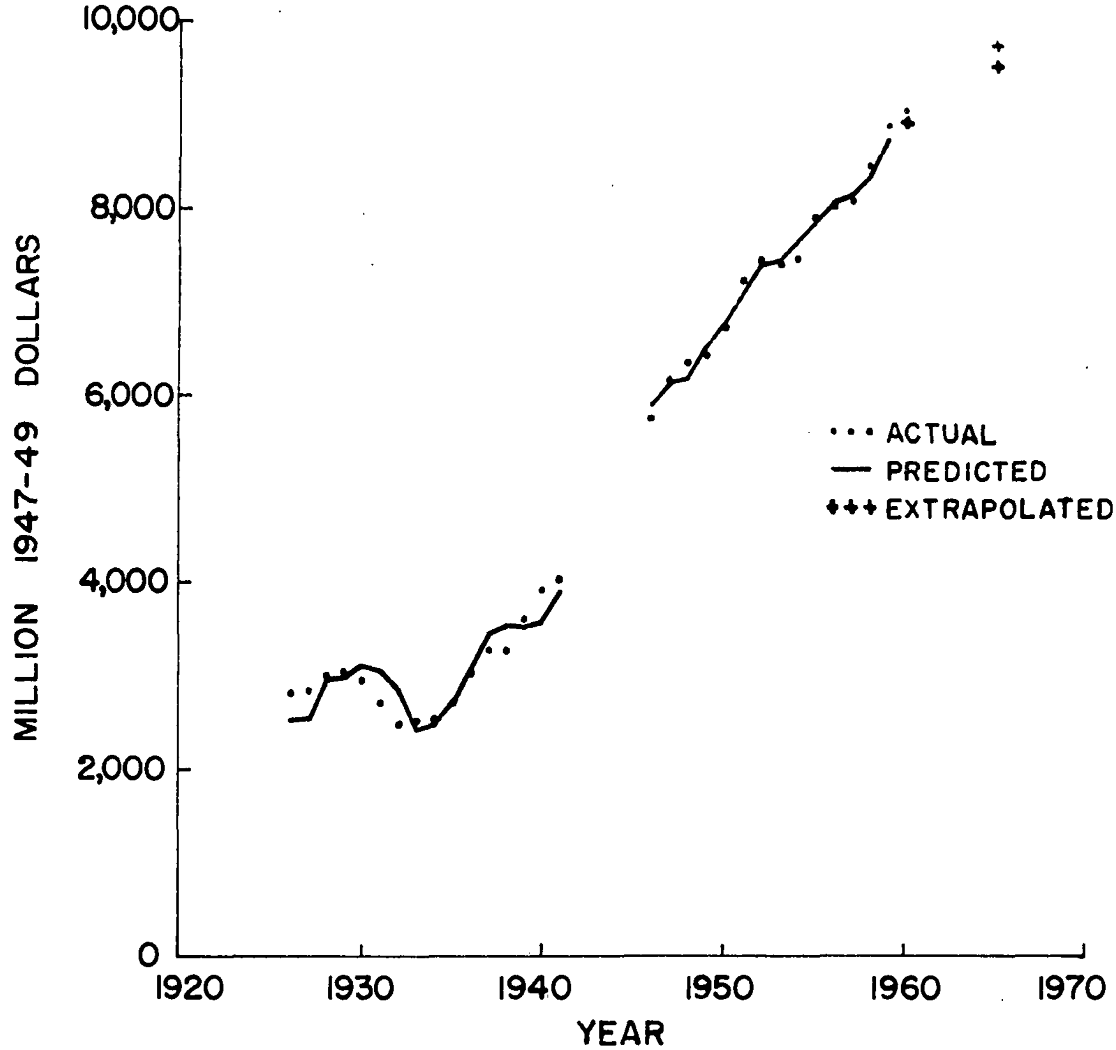

Figure 5. Trends in purchases of operating inputs Q_0 from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 6-0

continued upward and is nearly linear with no signs of dropping in recent years. Values of Q_0 estimated from equation 6-0 provide reasonably accurate predictions of the actual data. The extrapolated value for 1960 from equation 6-0 underestimates the actual value by 1.5 percent.

The terms predicted, projected and extrapolated are given particular meanings in this study. Values of the dependent variables are <u>predicted</u> only for years when values of the independent variables are known. Thus, if Q_0 is a function of past year variables, the quantity of Q_0 can be predicted for 1960 from known 1959 values of the explanatory variables. Estimates of the dependent variable outside the range of data to which the equation is fitted are called <u>extrapolations</u>. When the extrapolation involves arbitrary assumptions about the level of prices and other explanatory variables as for the year 1965, the estimates of the dependent variable are called <u>projections</u>.

The value of Q_0 is projected to 1965 assuming that prices will be at 1955-59 levels and that equation 6-0 is the appropriate demand relation. Two estimates of S_p are used. The first is based on a USDA projection of 112.4 billion 1947-49 dollars by 1965 (73). This projection agrees with the projected stocks from equation 9 assuming net farm income will remain at 1955-59 level. A second estimate of S_p of 114.4 billion 1947-49 dollars by 1965 is based on an investment function which contains an accelerator (Chapter 9, equation 28).[9] Stocks are estimated from the investment equation assuming farm output will increase eight percent by 1965.

Under the stated conditions, the demand quantities projected by equation 6-0 for 1965 are 7 and 10 percent above predicted 1960 levels if S_p is 112.4 or 114.4 billion dollars, respectively. Thus, unless important changes in the demand structure occur, purchases of Q_O are expected to increase considerably by 1965. The standard error and confidence limits of the projected quantity are not computed, but are expected to be large for extrapolations several years ahead.

Supply of Operating Inputs Estimated by Limited Information

The estimated supply function for operating inputs is

$$(13) \qquad P_{Ot} = 83.10 - \underset{(0.064)}{0.024}\, Q_{Ot} + \underset{(0.46)}{1.37}\, P_{NLt} + \underset{(0.10)}{0.34}\, C_t$$

where P_{NL} is the price of non-farm labor, C is a structural variable with value zero in the prewar years, 100 in the postwar years. P_O and Q_O, the endogenous variables, are defined earlier. P_{NL} and C are considered to be exogenous. The equation was estimated as part of an interdependent system of supply and demand equations for factory and product markets

[9]These projections should not be confused with those made for S_p in Chapter 9. In Chapter 9, we project S_p to the <u>end</u> of 1965; in this section to the <u>beginning</u> of 1965.

in agriculture from annual time series from 1926 to 1959, omitting 1942 to 1946.

The standard error (in parenthesis) of the coefficient of Q_O is more than twice as large as the coefficient. This evidence supports the hypothesis that the coefficient is zero and also supports the hypothesis that the supply elasticity is very large in the short run. That is, the reciprical of zero is an infinitely large number. There appears to be no basis from the operating input supply equation 13 for rejecting the hypothesis that the short run supply elasticity of operating inputs is very large. The results are also consistent with the assumption that price P_O is an exogenous variable in the least squares demand functions for Q_O.

Equation 13 indicates that a one percent increase in P_{NL} is associated with a 1.2 percent increase in P_O. The results point up the important interaction between economic forces in the farm and non-farm sectors. The implication is that an increase in non-farm wages tends to be reflected in a somewhat similar percentage increase in prices paid by farmers for operating inputs.

A second limited information model was estimated with slight modifications. In the second model, machinery purchases were adjusted to reflect the latent demand in 1946 and 1947. Also the weather variable W and government program variable G were omitted from the matrix of predetermined variables in the reduced form equations. (All the equations except 13 of the limited information empirical equations included in this study are from the <u>second</u> formulation.) The changes in the coefficients of the supply equation 14 estimated from the second model, is a manifestation of the

$$(14) \qquad P_{Ot} = 63.89 - \underset{(0.011)}{0.034}\, Q_{Ot} + \underset{(0.78)}{2.03}\, P_{NLt} + \underset{(0.17)}{0.47}\, C_t$$

sensitivity of the model to a change in specification. The same variables are included in equations 13 and 14. However, the magnitudes of the coefficients are somewhat larger in equation 14. The coefficient of Q_O is negative and large relative to the standard error. The positive coefficient of C indicates that the real supply price (the price of operating inputs relative to the implicit price deflator of the gross national product) of operating inputs has increased in the postwar period. Equation 14 suggests the hypothesis that the real price of operating inputs has declined because of a negatively sloped supply curve rather than because of technological changes that would be indicated by a negative coefficient of C. The incomplete specification of the supply equation and enigmatic nature of the limited information method indicate that equation 14 provides only a weak basis for such a hypothesis, however. Because the results in equation 13 appear to be more plausible than those in equation 14, we rely mainly on the elasticities estimated from equation 13 in subsequent sections.

Summary of Empirical Results

The increase in annual purchases of operating inputs by more than 200 percent from 1926 to 1959 has been a notable feature of the changing structure and increasing efficiency of American agriculture. Graphic analysis indicates that the substitution of operating inputs for other major inputs and the growing importance of purchased operating items in the total input mix is consistent with the secular decline in the price of operating inputs relative to other input and output prices.

To obtain an estimate of the relative impact of prices, technology and other influences on purchases, the demand for operating inputs was estimated by the least squares statistical technique. In addition, demand and supply of operating inputs were estimated at the farm level by limited information methods. Aggregate annual data from 1926 to 1959, omitting 1942 to 1945 were used in all the equations. Based on a priori considerations, the least squares equations tended to give the most realistic and meaningful estimates. Least squares equations estimated from data in original values, logarithms or first differences of original values gave quite comparable results. However, the logarithm equation explained slightly less of the annual variation in Q_0 and displayed more evidence of autocorrelation in the residuals than the single equations in original values.

The least squares demand equations indicated that approximately one-third of the increase in demand quantity may be attributed to short run price changes. The remaining portion of the increase is attributed to complementarity with growing levels of durable assets, technological changes, long run adjustments to price changes, increased farm size, and to improved knowledge, education and farm management.

The demand elasticity with respect to operating input price was estimated as -0.6 in the short run. Since operating input prices lagged more than one year were not significant, the elasticity with respect to P_O probably is not much greater in the long run than in the short run.

According to the results in Table 1, the short run demand elasticity with respect to farm prices received P_R is approximately 0.3. The long run elasticity potentially is greater than 2.0 because of the influence of product prices on the scale of plant. The equations suggest that an increase of one percent in the scale of the agricultural plant S_p may increase demand for operating inputs two percent after several years. Examples of this relationship are: (a) the increase in fertilizer applications due to additional land clearance, irrigation and drainage, and (b) additional requirements for gasoline and repairs as farm machinery stock is raised.

The limited information equation 13, expressing the supply of operating inputs at the farm level, is consistent with the hypothesis that the price elasticity of supply is infinite in the short run. The result suggests that changes in the demand quantities of fertilizer and other operating inputs have only a small influence on current input prices. The empirical result provides some support for a single equation estimate of demand for operating inputs -- the price may be considered an exogenous variable in the short run. The variable displaying the greatest impact on operating input price is the wage of non-farm labor. A one percent increase in the non-farm wage tends to be associated with a 1.2 percent increase in the price paid by farmers for operating inputs, according to equation 13. A discussion of the implications of this result in explaining the farm cost-price squeeze is deferred for a later chapter.

CHAPTER 6: THE DEMAND STRUCTURE OF SIX COMPONENTS OF OPERATING INPUTS

The optimum degree of aggregation in econometric analyses depends on the availability of research resources and the intended purpose of the analyses. In some instances the implications of a policy proposal can be observed more conveniently from a single macro equation containing some aggregation bias than from a series of highly refined but unintelligible micro equations. For some purposes, however, it is desirable to estimate the individual demand functions for several categories of Q_O. Each component of operating inputs does not react in exactly the same manner to prices and other economic stimuli. Some operating inputs such as fertilizer are more closely identified with the rising output and efficiency in agriculture than are building repairs, for example.

In Chapter 6 we analyze the demand for each of six components of operating inputs: (a) fertilizer and lime, (b) seed, (c) machinery supplies, (d) building repairs, (e) feed, and (f) miscellaneous inputs including dairy supplies, hand tools, electricity, etc. The livestock component is not considered because only a small portion of livestock inputs are of non-farm origin. Livestock marketing costs are included in miscellaneous inputs. Also, the structure of the livestock market has been analyzed in some detail by Mauldon (92).

The economic and statistical framework within which the demand for components of operating inputs is estimated is similar to that developed in the previous chapter. Since Chapter 6 essentially is a continuation of Chapter 5, the background and techniques need not be discussed extensively.

In each section, we review relevant literature and specify the demand function. All demand functions are estimated by single equation least squares with annual data from 1926 to 1959, excluding 1942 to 1945. After discussing the characteristics of the estimated demand equations, empirical estimates are made of price elasticities, changes in demand from 1926 to 1959, and projections of demand quantities to 1965.

Demand for Fertilizer and Lime

From 1929 to 1959, inputs of fertilizer and lime increased more than 500 percent, or at an annual compound rate of 5.6 percent. No other major agricultural input experienced as large an increase in use during the period.

Econometric studies of the aggregate demand for fertilizer estimated from times series by Griliches (45, 47) and by Heady and Yeh (57) were published in recent years. Griliches estimated the demand quantity of fertilizer as a function of the ratio of the fertilizer price to crop price and of the lagged fertilizer quantity variable. Using annual U.S. data from 1911 to 1956, he found the adjustment elasticity to be approximately 0.25. That is, approximately

25 percent of the adjustment of demand quantity to the equilibrium indicated by prices is completed in the short run. He estimated the elasticity of fertilizer demand to be approximately -0.5 in the short run and -2.0 in the long run. On the basis of the demand study, Griliches (45, p. 604) concluded that it is possible to explain the increased use of fertilizer on the basis of the declining relative price of fertilizer "without either invoking or even mentioning 'technological change'". He adds that technological changes such as improvement in production techniques and reduction in transportation costs have lowered the real price of fertilizer. Thus, his principal conclusion appears to be that technology has brought important changes in the supply of fertilizer, but not in the farm demand for fertilizer.

In 1961, Renshaw (102) demonstrated that the secular increase in demand for fertilizer is consistent with other hypotheses. He estimated the demand quantity of fertilizer as a function of relative price, the number of livestock on farms (natural fertilizer substitutes), acre-feet of irrigation water and lagged acreage planted to hybrid corn. The function, fitted to annual data from 1911 to 1958, explained 97.5 percent of the variation in fertilizer purchases. The coefficient of the price variable was considerably smaller than the standard error. Renshaw did not argue that the function was a meaningful expression of fertilizer demand.

His primary objective was to illustrate that the increased demand for fertilizer is consistent with hypotheses other than the declining real price of fertilizer. He concluded that the collinearity among plausible shift variables is too great to test hypotheses explaining the increased fertilizer consumption by statistical inference with a satisfactory degree of reliability.

Heady and Yeh (57) estimated the demand for fertilizer in aggregate and for individual nutrients for the U.S. and for each of ten regions. Coefficients were computed by single equation least squares using annual data from 1910 to 1956. The demand quantity was considered a function of fertilizer and crop prices, cash receipts from farming, cropland acreage and time. Price elasticity of demand at the national level was estimated as -0.49 and -1.71 with functions utilizing data for 1926-56 and 1910-56, respectively. The elasticity for various regions ranged from -0.4 in the Northeast to -3.8 in the Northern Plains. The coefficient for cropland acres was negative for the aggregate functions. Heady and Yeh concluded that this reflected the tendency of fertilizer to substitute for land in crop production. The authors consider several factors other than the fertilizer-crop price ratio to have influenced the rise in fertilizer use. The factors listed, e.g. the advent of new fertilizers, greater competition in sales, generally are associated with the supply side of the economic structure of the fertilizer industry.

Specification of the demand function

In this study the demand quantity of fertilizer is considered to be a function of relative prices, stocks of productive assets, weather, government programs and time. As a measure of plant size, cropland acres might be used rather than the stock of productive assets. Assets are used in this study because: (a) cropland acreage was not a significant variable in the study by Heady and Yeh, and (b) assets other than cropland such as cash held for productive purposes, machinery for applying fertilizer and investment in irrigation equipment may influence fertilizer sales. Limitations of statistical analysis precludes estimation of the effects of individual components of the asset structure. An additional reason for included productive assets is to preserve the parallelism with Chapter 5.

The demand function is specified explicitly as

(1) $Q_{Frt} = f\ ((P_{Fr}/P_R)_{t-1},\ (P_{Fr}/P_P)_{t-1},\ S_{pt},\ G_t,\ W_t,\ T)$.

The variables are defined as follows:

Q_{Frt} The dependent variable is a weighted two-price aggregate of fertilizer and lime inputs in the U.S. in the current calendar year (4). Crop year estimates are unavailable except for recent years, but a major portion, 75 percent, of all fertilizer is sold in the first six months of the year (45, p. 601). Further, the correlation is approximately 0.98 between recent values of the variable and fertilizer purchases on a crop year basis. The variable is in millions of 1947-49 dollars.

$(P_{Fr}/P_R)_{t-1}$ The past year index of the ratio of fertilizer and lime prices to the index of prices received by farmers for crops and livestock (120). P_R rather than crop prices is used because fertilizer is applied on crops fed to livestock. The expected profitability of fertilizer then depends on livestock rather than on crop prices.

$(P_{Fr}/P_P)_{t-1}$ The past year index of the ratio of fertilizer and lime prices to the index of prices paid by farmers for items used in production, including interest, taxes and wage rates (120). Fertilizer price is a component of P_P, but the influence is considered small because fertilizer is a small proportion of all inputs.

S_{pt} The stock of productive assets on January 1 of the current year (4, 123). The assets include real estate, machinery, livestock and feed, and cash held for productive purposes. S_p is expressed in billions of 1947-49 dollars.

G_t A current year index of the role of government policies on current input purchases. Years when acreage allotments or production controls are in force are given the value -1. Years when farm prices are supported are given the value +1. If supports are fixed, an additional +1 is added. These values are summed to form the index G (3, 34).

W_t Stalling's index of the influence of weather on farm output in the current year (108). Indices for 1958 and 1959 are not available from Stalling, but are constructed from an index of deviations from a linear trend of crop yields (124).

T Time, an index composed of the last two digits of the current year.

All price indices are adjusted to a 1947-49 base, i.e. 1947-49=100. All variables are annual observations for the U.S. from 1926 to 1959, excluding 1942 to 1945.

Demand equations estimated by least squares

Table 1 contains coefficients, standard errors and related statistics for single equation estimates of fertilizer and lime demand at the farm level. Equations 2, 3 and 4 are of the "conventional" type; equation 5 contains the lagged dependent variable Q_{Frt-1}. G is not significant in equation

Table 1. Demand functions for fertilizer Q_{Fr} estimated by least squa omitting 1942 to 1945; coefficients, standard errors (in pa

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_{Fr}/P_{R} t-1	P_{Fr}/P_{P} t-1	S_p t
2-0	0.996	1.32	-2707.45	-1.37	0.37	33.71
	0.99			(0.32)	(1.64)	(2.78)
3-0	0.996	1.43	-2987.01	-1.40	1.36	35.25
	0.99			(0.32)	(1.24)	(2.21)
3-L	0.98	1.11	-5.00	-1.18	1.33	3.49
	0.98			(0.22)	(0.66)	(0.80)
4-0	0.995	1.28	-2682.06	-1.14		34.10
	0.99			(0.17)		(1.84)
4-L	0.98	0.85	-0.66	-0.793		2.83
	0.98			(0.094)		(0.56)
4-F	0.48	2.18	--[d]	-0.82		25.05
	0.44			(0.32)		(6.33)
5-0	0.99	1.58	-79.32	-0.31		
	0.99			(0.22)		
5-L	0.98	1.30	1.62	-0.38		
	0.98			(0.14)		

[a]Sources and composition of the dependent variable Q_{Fr} and the i in the text.

[b]Equations are estimated in the transformations indicated: orig values in L equations), and first differences of original values F.

[c]The Durbin-Watson autocorrelation statistic d'.

[d]The intercept or constant coefficient in the first difference e in the 0 and L equations. The standard error of the coefficient was r

imated by least squares with annual data from 1926 to 1959,
andard errors (in parenthesis) and related statistics are included[a]

R	P_{Fr}/P_{P} $_{t-1}$	S_{P} $_{t}$	G $_{t}$	W $_{t}$	T	Q_{Fr} $_{t-1}$
'	0.37	33.71	-1.13	0.27	11.24	
)	(1.64)	(2.78)	(1.23)	(0.60)	(1.83)	
	1.36	35.25		0.35	11.49	
)	(1.24)	(2.21)		(0.59)	(1.81)	
	1.33	3.49		0.039	0.0149	
)	(0.66)	(0.80)		(0.156)	(0.0024)	
		34.10			10.55	
)		(1.84)			(1.61)	
3		2.83			0.0128	
4)		(0.56)			(0.0023)	
		25.05			17.42	
)		(6.33)			--[d]	
					5.26	0.907
)					(2.29)	(0.061)
					0.0095	0.57
)					(0.0028)	(0.12)

iable Q_{Fr} and the indicated independent variables are discussed

ns indicated: original values O, logarithms L (T is in original
riginal values F.

d'.

first difference equation is comparable to the coefficient of T
ne coefficient was not computed.

2 and is dropped to form equation 3. Since the effect of weather on fertilizer demand is not significant, W is omitted in equation 4. The coefficient of the price variable P_{Fr}/P_P is unstable in the first two equations in Table 1 because of a high correlation ($r = 0.91$) with S_p. After this price variable and W are dropped, the remaining variables explain up to 99 percent of the variability in fertilizer purchases according to equation 4. The high R^2 is misleading since much of the variation is explained by the slowly changing and easily predicted structural variables S_p and T. Removal of the linear trends by a first difference transformation reduces the R^2 approximately 50 percent.

Equation 4 indicates the fertilizer demand can be explained largely by variables lagged no more than one year. If equation 4 is correctly specified, a distributed lag model of the Koyck-Nerlove type does not seem appropriate. The addition of a lagged dependent variable representing past influences on Q_{Fr} could increase the explanation of the current demand quantity very little. Also, since the correlation between Q_{Frt} and Q_{Frt-1} is high, the correlation between Q_{Frt-1} and the explanatory variables in equation 4 also are likely to be high.

The first three equations essentially are short run because of the S_p or scale-of-plant variable. To estimate long run elasticities and to test empirically the appropriateness of the distributed lag model, equation 5 is included. Again a high percent of the variability in the demand quantity is explained. Equations estimated in logs (5-L) and original values (5-O) provide different estimates of the adjustment coefficient.[1] Time T and lagged quantity are correlated to the extent r = 0.95. In equation 5-O, the coefficient of the lagged quantity is dominant.

The high R^2 values of equations estimated in untransformed (original) data indicate that a linear function is satisfactory for estimating the demand for fertilizer. The test for autocorrelation is inconclusive at the 95 percent probability level in equation 4-O. However, the hypothesis of zero autocorrelation is rejected in equation 4-L. The first difference transformation results in a considerable reduction in autocorrelation according to equation 4-F -- d' is not significant. Although the magnitudes of the coefficients and standard errors are altered somewhat by the transformation, the coefficients remain statistically significant. The higher values of d' in equations 5-O and 5-L do not necessarily indicate less autocorrelation than in equation 5 because the Durbin-Watson test tends to be biased when

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[1]The adjustment coefficient of equations estimated in logs and orginal values differ somewhat in concept. In the logarithm equation, the coefficient is an elasticity. The difference in concept is not expected to explain the larger difference in magnitudes found in equation 5, however.

lagged dependent variables are included. That is, the autoregressive structure tends to be absorbed in the coefficients of the independent variables. The coefficients may be biased for this reason.

Price elasticity of demand

The price elasticity of short run demand for fertilizer and lime with respect to P_{Fr} computed from equation 4-O is -0.26. The point estimate and 95 percent confidence interval of short run price elasticity given by equation 4-L is -0.79 ± 0.19. An average of these estimates -0.5 agrees with the results obtained by Griliches and with the lower result obtained by Heady and Yeh. It may be reasonable to conclude that a one percent decrease in fertilizer price (or a one percent increase in prices received by farmers) tends to be associated with a one-half percent increase in fertilizer purchases by farmers in the short run.

The simple correlation between $(P_{Fr}/P_R)_{t-1}$ and S_{pt} (or T) approximately is 0.70, and there appears to be sufficient independent variation in price to obtain a reliable estimate of the short run price elasticity. The simple correlations between the trend variables S_p, T and Q_{Frt-1} are quite high, however. This precludes placing a high degree of confidence in estimates of long run price elasticities whether estimated by (a) a recursive form such as equation 4 or (b) the distributed lag model such as equation 5. Long run elasticities are computed from these equations, nevertheless, but should be regarded as hypotheses rather than as final, exact estimates. Equation 4 indicates that the long run elasticity with respect to P_{Fr} is no greater than the short run elasticity. Equation 4-L implies that a one percent increase in S_p increases fertilizer consumption over two percent. Equation 28, Chapter 9 indicates that the long run elasticity of S_p with respect to P_R/P_P is nearly unitary. Hence, the long run elasticity of Q_{Fr} with respect to P_R/P_P potentially is greater than two. The "long run" is very distant -- equation 28, Chapter 9 indicates that 20 years are required to make 90 percent of the long run adjustment. Equation 5-L indicates that the adjustment coefficient is 0.43. The short run elasticity with respect to P_R/P_{Fr} is -0.4, and that long run elasticity is -0.9 according to equation 5-L. It is interesting to note that despite the difference in magnitude of the adjustment coefficients in equations 5-0 and 5-L, the estimated long run elasticities with respect to P_{Fr}/P_R are similar, i.e. -0.8 and -0.9, respectively.

Shifts in demand

To interpret the coefficient of S_p strictly as a complementarity of fertilizer sales with growth of the farm plant, is somewhat restrictive. In reality, S_p is correlated with the time variable. Both variables are correlated with gradual changes in the structure of fertilizer demand which, though important, could not be introduced into the demand equation. Since the specification is not complete, it is advisable to interpret the coefficients of the two variables collectively, rather than individually.

Influences represented by S_p and T exert a large impact on the demand quantity. Consider the standard partial regression coefficients of the variables in equation 3-0: -0.12 for $(P_{Fr}/P_R)_{t-1}$, 0.67 for S_{pt} and 0.24 for T. These results indicate that the relative impact of short run price is less than that of S_p and T on fertilizer consumption. The actual proportion of a secular increase in fertilizer consumption attributed to a variable depends on the movement of the variable through time as well as on the regression coefficient. The real price of fertilizer P_{Fr}/P_R declined slightly over 30 per cent from 1926 to 1959. If the real price of fertilizer is set at the 1959 value and other variables are set at the 1926 values, equation 4-0 indicates that the demand quantity would be only 30 percent greater than the predicted 1926 quantity. The implication is that over 400 of the 512 percent increase in fertilizer consumption from 1926 to 1959 remains to be explained by variables other than short run price. The correlation between the price variable and the two trend variables S_p and T is not high and does not preclude a reliable estimate of <u>short run</u> price on the demand quantity.

Unfortunately, variables such as Q_{Frt-1} and S_{pt} included in the demand function to estimate the long run price effects are highly correlated with other trend variables. It is necessary, therefore, to include the long run price influences with other factors in an "aggregate" explanation of the secular rise in fertilizer consumption.

Many important, gradual influences other than short run price are reflected in the coefficients of S_p and T. Some are technological, others must be classified more broadly. As the nutrient levels in virgin soils decline, the demand curve for fertilizer shifts upward. Introduction of hybrid seeds, drainage of wet areas, and irrigation also increase the response of crops to fertilizer and raise demand. The efforts of extension services, high schools and college agricultural classes and other educational groups have brought an increasing awareness of potential returns from fertilizer. Improved farm machinery for applying fertilizer, liquid nitrogen and bulk spreading by commercial firms also should not be overlooked. Competition is another factor responsible for increased fertilizer consumption. Farmers must use efficient farming practices to pay their bills and provide good livings for their families especially during periods of declining relative farm prices. Those who are not efficient tend to be forced out and gradually replaced by farmers who are more efficient -- who use more fertilizer. It is notable that increases in farm size are correlated very highly with S_p.

Better farm managers may not only increase per acre fertilizer application on crops which respond well to fertilizer, but they also intensify the rotation toward these crops. For example, there is a trend in Iowa toward rotations containing a higher proportion of corn. Undoubtedly, there is some interaction between prices and structural changes indicated above. Because of collinearity among explanatory variables other than short run price in the demand function, the relative impact of long run price influences, technology and other influences cannot be determined precisely. The above discussion suggests that all have been important influences on the secular rise in fertilizer consumption.

Trends and projections

Figure 1 indicates that purchases of fertilizer rose steadily from 1926 to 1960 with the exception of the depression years of the early 1930's. The increase is approximately linear during the postwar period. Barring changes in structure, a linear extension of the postwar trend could provide a useful estimate of demand quantities in the near future.

The predicted quantities from equation 4-0 fit the actual observations reasonably well. In recent years, a tendency exists to underestimate fertilizer purchases. The extrapolated estimate of 1960 purchases from equation 4-0 underestimates actual purchases by approximately three percent.

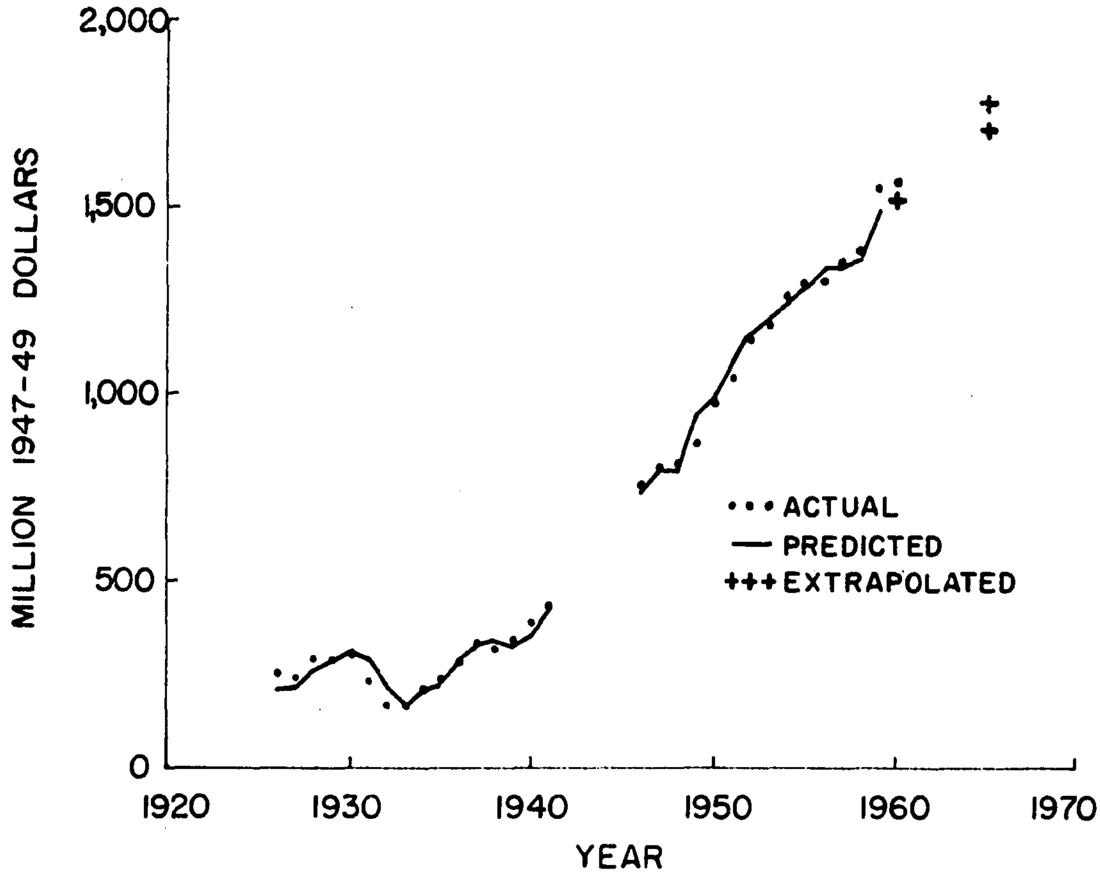

Figure 1. Trends in purchases of fertilizer Q_{Fr} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 4-0

Perhaps acreage restrictions encouraged substitution of fertilizer for cropland. Failure to account for this structural change in equation 4-0 may explain the tendency for predicted purchases to be lower than actual purchases in recent years.

Purchases are projected to 1965 assuming prices are averages of the 1955-59 period. Two estimates of S_p are used in equation 4-0. The lower estimate based on USDA (73) projections is 112.4 billion 1947-49 dollars by 1965. This estimate also agrees with the predicted level of stock from investment equation 23, Chapter 9, assuming farm income remains at 1955-59 levels. The higher estimate, 114.4 billion 1947-49 dollars, is based on a second investment function which includes an accelerator coefficient (cf. equation 28, Chapter 9). Stocks are estimated from this investment equation based on a USDA (73) projection of an eight percent increase in farm output by 1965.

The projected estimates from equation 4-0 shown in Figure 1 are made on the assumption that parameters of the fertilizer demand function for 1926 to 1959 remain unchanged until 1965. Under the stated conditions, purchases of fertilizer in 1965 is expected to be 12 percent and 17 percent over predicted 1960 levels for S_p equal to 112.4 and 114.4, respectively. The confidence limit of the estimates are not computed, but are expected to be large for extrapolations several years ahead. Nevertheless, on the basis of strong past trends and projections from equation 4-0, a large increase in fertilizer demand is expected by 1965.

Demand for Seed

From 1926 to 1959, purchases of seed increased over 200 percent, or at an average compound rate of 3.5 percent per year. Substitution of purchased seed for farm produced seed is an important aspect of the changing structure of American agriculture. The role of prices and other influences in the demand function for seed are examined in this section.

Although there have been no previous estimates of the demand function for seed in the U.S., Griliches (48), explored the factors responsible for the differential rate of adoption of hybrid corn in a study published in 1957. He fitted the logistic curve to data from crop areas in several states. The rate of adoption was found to be a function of the relative profitability of hybrid corn, market density, corn acres per farm, date of origin of hybrid introduction and other less important factors.

Specification of the demand function

These variables provide a basis for the specification of the seed demand function. The relative profitability of seed is indicated by price variables. At a national level, several of these influences have appeared gradually and can be represented by a time variable. The lag effect may be accommodated by lagging the dependent variable. In the following analysis, the quantity of seed purchases is estimated as a function of the ratios of seed prices to prices received and to prices paid, the scale of the agricultural plant, government policies, weather and slowly changing factors represented by the time variable. The variables are defined as follows:

Q_{Sdt} The dependent variable is the annual seed purchases by U.S. farmers during the current year in millions of 1947-49 dollars (120, 121). Inter-farm sales are included. The variable is computed by dividing total farm expenditures for seed by the index of prices paid by farmers for seed. The implicit price deflator converts expenditure data to "quantity" measured in constant 1947-49 dollars. An estimate of the actual quantity of seed inputs was unavailable.

$(P_{Sd}/P_R)_{t-1}$ An index of the past year ratio of seed prices to prices received by farmers for crops and livestock (120). Livestock prices are included because for many crops fed to livestock, the crop price is not the only decision variable.

$(P_{Sd}/P_P)_{t-1}$ An index of the past year ratio of seed price to prices paid for items used in production, including interest, taxes and wage rates (120).

All price indices are adjusted so that the 1947-49 average is 100. Four additional variables S_{pt}, W_t, G_t and T are specified in the demand function. The logic and sources of these variables are discussed in the previous section on fertilizer demand. The equations are estimated with annual U.S. data from 1926 to 1959, excluding the war years 1942 to 1945. The data are not considered adequate for estimating demand equations over alternative time periods.

The estimated demand equations

The coefficients, standard errors and other statistics of single equation estimates of seed demand from the foregoing data are presented in Table 2. A large percent of the annual variation ($\bar{R}^2 = 0.94$) is explained by the six independent variables in equation 6-0. The institutional variable G is significant at the 95 percent probability level. The approximate nature of the variable prohibits placing great reliance on the coefficient. The significance of the coefficient is not surprising, since acreage restrictions that reduce cropland acres would be expected to reduce seed demand because seed is a complement of land. Due to the somewhat dubious construction of the G variable, it is dropped to form equation 7. The coefficients of the weather variable are not significantly different from zero. If weather affects seed demand, the specifications of equations 6 and 7 are unable to detect

Table 2. Demand functions for seed Q_{Sd} estimated by least square
1942 to 1945; coefficients, standard errors (in parenth

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_{Sd}/P_R t-1	P_{Sd}/P_P t-1	
6-0	0.95	1.29	-156.93	0.80	0.47	-3
	0.94			(0.84)	(0.76)	(2
7-0	0.94	1.09	-61.57	-0.59	1.55	-4
	0.93			(0.73)	(0.72)	(2
7-L	0.92	1.30	4.23	-0.12	0.43	-1.
	0.91			(0.25)	(0.19)	(0.
8-0	0.93	0.63	-322.64	-0.31	2.02	
	0.92			(0.74)	(0.69)	
8-L	0.90	0.69	0.76	0.028	0.56	
	0.89			(0.259)	(0.19)	
9-0	0.93	0.61	-357.38		1.93	
	0.93				(0.65)	
9-L	0.90	0.69	0.81		0.57	
	0.89				(0.18)	
9-F	0.33	2.25	--[d]		1.84	
	0.30				(0.52)	
10-0	0.97	2.03	-229.75		1.80	
	0.96				(0.47)	
10-L	0.95	2.21	-0.23		0.52	
	0.94				(0.14)	

[a]Sources and composition of the dependent variable Q_{Sd} and th
discussed in the text.

[b]Equations are estimated in the transformations indicated: c
original values in L equations), and first differences of original

[c]The Durbin-Watson autocorrelation statistic d'.

[d]The intercept or constant coefficient in the first differenc
of T in the O and L equations. The standard error of the coeffici

stimated by least squares with annual data from 1926 to 1959, omitting
ndard errors (in parenthesis) and related statistics are included[a]

P_{Sd}/P_R t-1	P_{Sd}/P_P t-1	S_p t	G t	W t	T	Q_{Sd} t-1
0.80	0.47	-3.49	2.89	0.85	16.02	
(0.84)	(0.76)	(2.28)	(1.08)	(0.67)	(1.87)	
-0.59	1.55	-4.43		0.88	17.28	
(0.73)	(0.72)	(2.52)		(0.75)	(2.03)	
-0.12	0.43	-1.81		0.19	0.0222	
(0.25)	(0.19)	(0.72)		(0.21)	(0.0027)	
-0.31	2.02				14.35	
(0.74)	(0.69)				(0.91)	
0.028	0.56				0.0162	
(0.259)	(0.19)				(0.0012)	
	1.93				14.55	
	(0.65)				(0.76)	
	0.57				0.0162	
	(0.18)				(0.0010)	
	1.84				17.20	
	(0.52)				--[d]	
	1.80				5.70	0.62
	(0.47)				(1.84)	(0.12)
	0.52				0.0064	0.60
	(0.14)				(0.0022)	(0.13)

dent variable Q_{Sd} and the indicated independent variables are

formations indicated: original values O, logarithms L (T is in
differences of original values F.

atistic d'.

t in the first difference equation is comparable to the coefficient
rd error of the coefficient was not computed.

it. The coefficient of S_p is not significantly different from zero in equations 6-0 and 7-0 and is just significant at the 95 percent level in equation 7-L. The low significance of S_p in the equations in original values, the relatively high correlation with T and the questionable sign of the coefficient suggest dropping the variable (and W) to form equation 8. The omission of the variables reduces the R^2 only slightly and increases the magnitude and significance of the coefficient of $(P_{Sd}/P_P)_{t-1}$. The coefficients of $(P_{Sd}/P_R)_{t-1}$ are not significantly different from zero in equations 6, 7 and 8. Thus, the variable is dropped -- the result is equation 9. The two variables $(P_{Sd}/P_P)_{t-1}$ and T predict seed purchases very well. The coefficients of both variables are significant.

Unfortunately, autocorrelation in the residuals has increased considerably as variables are dropped. The presence of autocorrelation as measured by d' is inconclusive in equations 6 and 7, but significant in equations 8 and 9. Equation 9-F, estimated in first differences of original values, reduces autocorrelation to a non-significant level. The magnitude and significance of the price coefficients in equation 9-F and 9-0 are not appreciably different.

Statistical properties of equation 10, estimated with lagged Q_{Sd}, and considerations from previous analysis indicate that the distributed lag equation may be a useful model of seed demand. The R^2 is increased, autocorrelation is reduced (the test is biased, however) and significance of the price coefficients is greater in equation 10 than in equation 9. The lagged adoption of new seed varieties because of limitations on seed stock expansion, or lack of awareness and cautious recognition of new varieties by farmers may justify the lagged adjustment model. The coefficients indicate that approximately 40 percent of the adjustment to equilibrium prices and technological conditions indicated by T are made in the short run.

Price elasticity of demand

The equations in Table 2 indicate that the price elasticity of seed demand with respect to prices received by farmers is zero. That an increase in seed prices relative to prices received would depress seed purchases very little seems reasonable from considerations of the production process. There are no important substitutes for seed in the production process. If production is to occur at all, the farmer must use seed. Seed purchases are a small portion of total production costs, hence, a change in seed price would not be expected to influence the profitability of production appreciably. Furthermore, the complementarity of seed with the relatively fixed land input also causes stability in seed sales. Land inputs have a low reservation price and tend to be fixed in the short run.

The coefficient of P_{Sd}/P_P is not significantly different from zero in equation 6. If the equation is the correct specification, changes in seed prices with respect to other input prices can be expected to result in little change in seed purchases. In the remaining equations in Table 2, however, the coefficient of the variable is significant. The significant coefficient may be reflecting the influence of variable G, omitted in equations 7 to 10. P_{Sd}/P_P contributes significantly to the explanation of Q_{Sd} and is useful from a positivistic, predictive standpoint. But additional analyses are needed to determine the structural role of the variable in the demand function.

Shifts in demand

Structural changes account for a major portion of the 213 percent growth in seed demand from 1926 to 1959. The dominance of time in the demand equation 12-0 is illustrated by the standard partial regression coefficients 0.15 and 0.97 for P_{Sd}/P_P and T, respectively. If price is at the 1959 level and T is at the 1926 value, the demand quantity would be approximately 14 percent less than the predicted quantity for 1926 in equation 12-0. Nearly the entire 3.5 percent annual compound increase in demand must be explained by structural rather than price changes.

The most important element in the changing structure of the seed market is the introduction of hybrid corn and other improved seed varieties. The improved seeds are more resistant to enemies of crops such as insects and fungi. In many instances, improved varieties not only maintain yields against natural enemies, but their genetic vigor provides opportunities for raising yields.

Factors other than improved seeds have been important in explaining the growth of seed purchases from 1926 to 1959. Equation 10 indicates that lagged adjustment to price and technology also helps explain the greater demand in 1959. Other factors responsible for the rising demand for purchased seed are the weakened resistance of farm produced seeds to natural enemies, shifts toward more seed intensive rotations, and improved management encouraged by the cost-price squeeze.

Trends and projections

Figure 2 indicates that seed purchases remained relatively stable during late 1920's and early 1930's. Purchases rose sharply after the depression and continued to increase in the postwar years, but at a lower rate. Predicted values of seed purchases from equation 10-0 provide reasonable approximations to the actual values. Extrapolation of the quantity estimate for 1960 from past data underestimated the actual 1960 purchases by two percent.

Seed purchases are estimated for 1965 from equation 10-0. The estimated quantity, 706 million 1947-49 dollars,

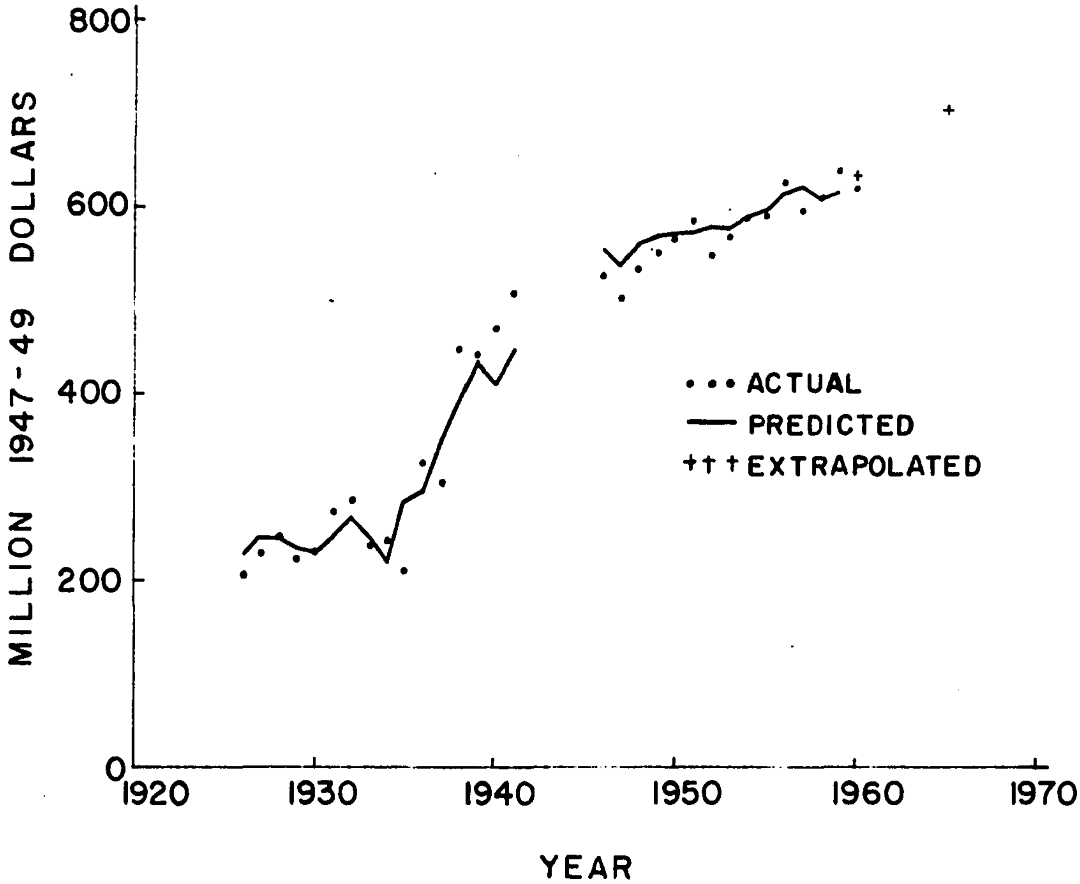

Figure 2. Trends in purchases of seed Q_{Sd} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 10-0

is 12 percent above the 1960 predicted level. The projection is based on the assumptions that prices will remain at average 1955-59 levels, and that the structure will continue to change as indicated by the time coefficient.

Because errors tend to accumulate in equations such as 10-0 containing lagged dependent variables, caution must be used in interpreting projections several years in advance. It may be of some assurance to note that the projected estimate for 1965 is comparable to a linear extension of the postwar trend in seed purchases.

Demand for Machinery Supplies

Inputs of machinery supplies, including fuel, oil, lubrication and repairs, increased 365 percent from 1926 to 1959. The average compound rate of increase was 4.8 percent per year. Undoubtedly, the growth in purchases of machinery supplies has been closely associated with the growth of machinery inventories because of the complementarity between the inputs. Other factors such as price may also have been important in the changing demand structure for machinery supplies. The purpose of this section is to analyze the role of prices and other factors in determining the demand quantities of machinery supplies.

Specification of the demand function

The demand quantity of machinery supplies is considered a function of current and past year prices of machinery supplies, prices received by farmers, prices paid by farmers for production items, the stock of productive assets, government agricultural policies, weather and gradually shifting influences represented by a time variable.

Due to the anticipated strong complementarity between machinery stocks and machinery operating inputs (supplies), the specification of machinery stocks in the demand function is advisable. Productive assets other than machinery stocks also influence sales of machinery supplies, but due to the high correlation between machinery inventories and other components of productive assets, it is feasible to include only one variable. The included variable, total stocks of productive assets S_p, is correlated with machinery stocks from 1926 to 1959 to the extent $r = 0.98$. Thus the coefficient of S_p in the demand equation must be interpreted as the joint influence of machinery stocks and other productive assets on the demand quantity.

The variables in the demand function are:

Q_{MSt} The dependent variable is the annual U.S. purchases of machinery supplies during the current calendar year in millions of 1947-49 dollars (4). Machinery supplies included fuel, lubrication, oil and repairs of motor vehicles and other farm machinery used for productive purposes.

$(P_{MS}/P_R)_t$ The current year index of the ratio of prices paid by farmers for motor supplies to prices received by farmers for crops and livestock (120). Both current and past year prices are included in the demand function.

$(P_{MS}/P_P)_{t-1}$ The past year index of the ratio of prices paid by farmers for motor supplies to prices paid by farmers for items used in production, including interest, taxes and wage rates (120).

The demand function also includes an index of government policies G, a weather index W, the stock of productive assets on January 1, S_p, and a time variable T. The logic and sources of these variables is discussed in more detail in the section on demand for fertilizer.

The estimated demand equations

Equation 11-0 in Table 3 contains current and past prices of motor supplies and other variables which together explain 99 percent of the variation around the mean of Q_{MS}. If government policies influence demand for machinery supplies, it is not apparent from the insignificant coefficient of G in equation 11-0. The variable is dropped to form equation

Table 3. Demand functions for machinery supplies Q_{MS} estimated by le
omitting 1942 to 1945; coefficients, standard errors (in pa

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_{MS}/P_R t	P_{MS}/P_R t-1	P_{MS}/P_P t-1
11-0	0.99	0.96	-798.38	-2.02	0.78	-7.72
	0.99			(0.64)	(0.86)	(2.42)
12-0	0.99	0.97	-162.97	-2.28	0.95	-10.00
	0.99			(0.62)	(0.87)	(1.84)
12-L	0.996	1.23	4.05	-0.298	-0.067	-0.72
	0.995			(0.072)	(0.109)	(0.18)
13-0	0.99	0.98	-383.08		-1.47	-7.95
	0.99				(0.67)	(2.10)
13-L	0.99	1.25	3.91		-0.412	-0.49
	0.99				(0.091)	(0.22)
14-0	0.99	0.91	-270.65	-1.79		-8.56
	0.99			(0.41)		(1.25)
14-L	0.996	0.98	4.30	-0.336		-0.80
	0.995			(0.049)		(0.12)
15-0	0.997	1.29	350.56	-1.11		-1.75
	0.996			(0.25)		(1.13)
15-L	0.998	1.45	1.16	-0.264		0.046
	0.998			(0.029)		(0.148
16-0	0.997	1.29	143.95	-1.20		
	0.996			(0.25)		
16-L	0.998	1.40	1.33	-0.264		
	0.998			(0.028)		

[a]Sources and composition of the dependent variable Q_{MS} and the i
the text.

[b]Equations are estimated in the transformations indicated: orig
values in L equations).

[c]The Durbin-Watson autocorrelation statistic d'.

estimated by least squares with annual data from 1926 to 1959,
'd errors (in parenthesis) and related statistics are included[a]

MS/P_R t-1	P_{MS}/P_P t-1	S_p t	G t	W t	T	Q_{MS} t-1
0.78	-7.72	22.55	3.82	1.09	26.58	
0.86)	(2.42)	(4.68)	(2.71)	(1.22)	(3.63)	
0.95	-10.00	19.16		1.14	26.58	
0.87)	(1.84)	(4.10)		(1.24)	(3.70)	
·0.067	-0.72	0.27		0.084	0.01448	
0.109)	(0.18)	(0.25)		(0.067)	(0.00096)	
·1.47	-7.95	17.78			31.66	
0.67)	(2.10)	(4.85)			(4.15)	
·0.412	-0.49	0.21			0.0159	
0.091)	(0.22)	(0.31)			(0.0011)	
	-8.56	19.80			27.82	
	(1.25)	(4.02)			(3.46)	
	-0.80	0.29			0.01423	
	(0.12)	(0.24)			(0.00092)	
	-1.75				9.35	0.765
	(1.13)				(3.47)	(0.077)
	0.046				0.0044	0.72
	(0.148)				(0.0016)	(0.11)
					6.63	0.855
					(3.02)	(0.050)
					0.00479	0.690
					(0.00091)	(0.044)

.e Q_{MS} and the indicated independent variables are discussed in

.ndicated: original values O, logarithms L (T is in original

12. The coefficient of the past year price of motor supplies relative to prices received is not significantly different from zero. The complete dominance of current price over past year price is inconsistent with a priori considerations. The magnitude of the $(P_{MS}/P_R)_{t-1}$ coefficient may partially be explained by high correlation ($r = 0.89$) between current and past year price. That is, the current price variable tends to absorb the effect of past year price. A similar result is avoided for the second major price variable P_{MS}/P_P, by including only past year price. It is impossible to differentiate effects of the variable by years because of the high correlation ($r = 0.96$) between current and past year values of P_{MS}/P_P.

The tendency for current or past year price to absorb the effect of the other in regression analysis is apparent in equations 11, 13 and 14. The insignificant weather variable W and current price are deleted from equation 12 to form equation 13. Equation 14 is similar to equation 13, with current values substituted for past values of P_{MS}/P_R. The coefficient of $(P_{MS}/P_R)_{t-1}$ is negative and significant in equation 13 although it was not significantly different from zero in equation 12. The significance of the coefficient is less than the significance of the coefficient of current price in equation 14, however. Equation 13 is useful for predictive purposes when current price is unknown. If current and past year prices continue to be related, prediction from past prices can be made with suitable accuracy.

All coefficients are significant in equations 13 and 14 except the coefficient of S_p in the equations estimated in logarithms. S_p is specified in the demand function to reflect the influence of durable assets, particularly machinery inventories, on the demand for machinery supplies. Previous knowledge of the complementary relationship between machinery inventories and purchases of Q_{MS} suggests a significant positive coefficient of S_p is appropriate. From this standpoint, the equations in original values are more acceptable. But the equations estimated in logarithms display less autocorrelation as indicated by d'. The test of the null hypotheses that the residuals are uncorrelated in the logarithm equations is inconclusive in equations 12-L and 13-L, but is rejected at the 95 percent level in equation 14-L.

Equations 15 and 16 are equivalent to equation 14 with the lagged quantity substituted for S_p to form an alternative estimate of the long run properties of the demand function. Equations 11 to 14 indicate that the distributed lag model may be inappropriate because a large proportion of the variation in demand quantity is explained by variables lagged no more than one year. The coefficient of $(P_{MS}/P_R)_t$ is relatively stable and significant in the difference equation 15. The coefficient of $(P_{MS}/P_P)_{t-1}$ is insignificant, however, possibly because of inappropriate model specification. The latter variable is omitted in equation 16. All variables are significant and possess the anticipated signs. Together the variables explain over 99 percent of the annual variation about the mean of Q_{MS}. The distributed lag equation 15 indicates that about 25 percent of the adjustment Q_{MS} to the equilibrium level is made in the short run.

Price elasticity of demand

From Table 3, the estimated price elasticity may be computed with respect to each of the price variables P_R, P_P and P_{MS}. Considering first P_{MS}, the total price elasticity of demand with respect to P_{MS} is the sum of the direct component (P_R) and the substitution component (P_P). On the basis of equation 14-O, the estimated total elasticity with respect to P_{MS} is -0.22 (the direct component) plus -0.82 (the substitution component) or -1.0. Similarly, the estimated elasticity from equation 14-L is -0.34 (the direct component) plus -0.80 (the substitution component) or -1.1. It may be noted that these estimates are comparable to the long run estimates of elasticity with respect to P_{MS} from equations 16-O and 16-L of -1.0 and -0.9, respectively.

Equation 14-O indicates that the short run demand elasticity with respect to P_R is 0.22. The same equation in logarithms gives a point estimate and confidence interval of

-0.34 ± 0.10. The results imply that the short run price elasticity with respect to P_R approximately is 0.3. The long run elasticity is much greater, however. A sustained rise in prices received by farmers increases machinery stock from two to three percent according to Chapter 8. Because equation 14-0 indicates that a one percent rise in S_p raises demand for Q_{MS} more than one percent, the demand elasticity of machinery supplies may be more than two in the long run. Purchases of motor supplies are more sensitive to P_R than to P_{MS} in the long run because of the complementarity of the input with durables, particularly with machinery. The long run is more than 10 years according to Chapter 8, however.

Shifts in demand

Equation 14-0 indicates that if prices are at 1959 levels, other variables at 1926 levels, the quantity demanded of machinery supplies would be 119 percent greater than the predicted 1926 demand quantity. Even if allowances are made for lagged adjustment to short run price changes, it is likely that much of the 365 percent increase in demand would remain to be explained by factors other than price. The strongest influence on demand for machinery supplies has been the rising investment in farm machinery, particularly motor vehicles. The complementarity between machinery stock and Q_{MS} is indicated by the positive coefficient of S_p and T.

Due to incomplete specification and correlations among trend variables, the exact influence of machinery investment on purchases of supplies is not ascertainable. Stock of all farm machinery increased nearly 150 percent from 1926 to 1959. If purchases of machinery supplies increase accordingly, this would explain a considerable portion of the total increase in demand for machinery supplies.

After exhausting the (a) short run price and (b) complementarity with machinery inventories hypotheses, approximately one-third of the total increase in annual sales remains to be explained by additional influences. One important influence is the increased requirement of fuel and oil *per unit* of machinery stock. As motor vehicles become a more prominent component of machinery stock, requirements for gasoline and oil increase. Also, more intensive tillage practices require additional operating inputs.

The role of technology in the demand for motor supplies appears to be primarily indirect. Rather than direct improvements in repairs, fuels, oils and lubricants, the improvements have been indirect through more efficient engines, more durable, convenient machines, and machinery designed for new uses.

Trends and projections

Except for a small dip during the early 1930's, the quantity of machinery supplies purchased by farmers has increased steadily until 1949 (Figure 3). From 1950 to the present, the upward trend does not appear to be as dominant, and some slight setbacks in sales have occurred. The predicted values of annual purchases from equation 13-0 provide reasonable approximations to the actual data. The equation predicts the downturns in the early 1930's, in 1950 and 1954, but does not correctly gage their magnitudes. The extrapolated demand "quantity" in 1960 is 2415 million 1947-49 dollars, and is three percent greater than the actual estimate of 2341 million 1947-49 dollars. The "actual" estimates are often revised and the percent of error may change. Assuming prices are at average 1955-59 values, that stocks of productive assets increase to 112.4 billion 1947-49 dollars by 1965, and that the influence of technology and other variables represented by the time variable continue as in the 1926-59 period, purchases of Q_{MS} totalling 2622 million 1947-49 dollars are estimated for 1965. If productive assets increase to 114.4 billion 1947-49 dollars, the projected estimate of machinery supply purchases is 2659 million 1947-49 dollars by 1965. The estimates are nine and 10 percent, respectively, above 1960 predicted levels. The projections are approximately equivalent to estimates that would be found by

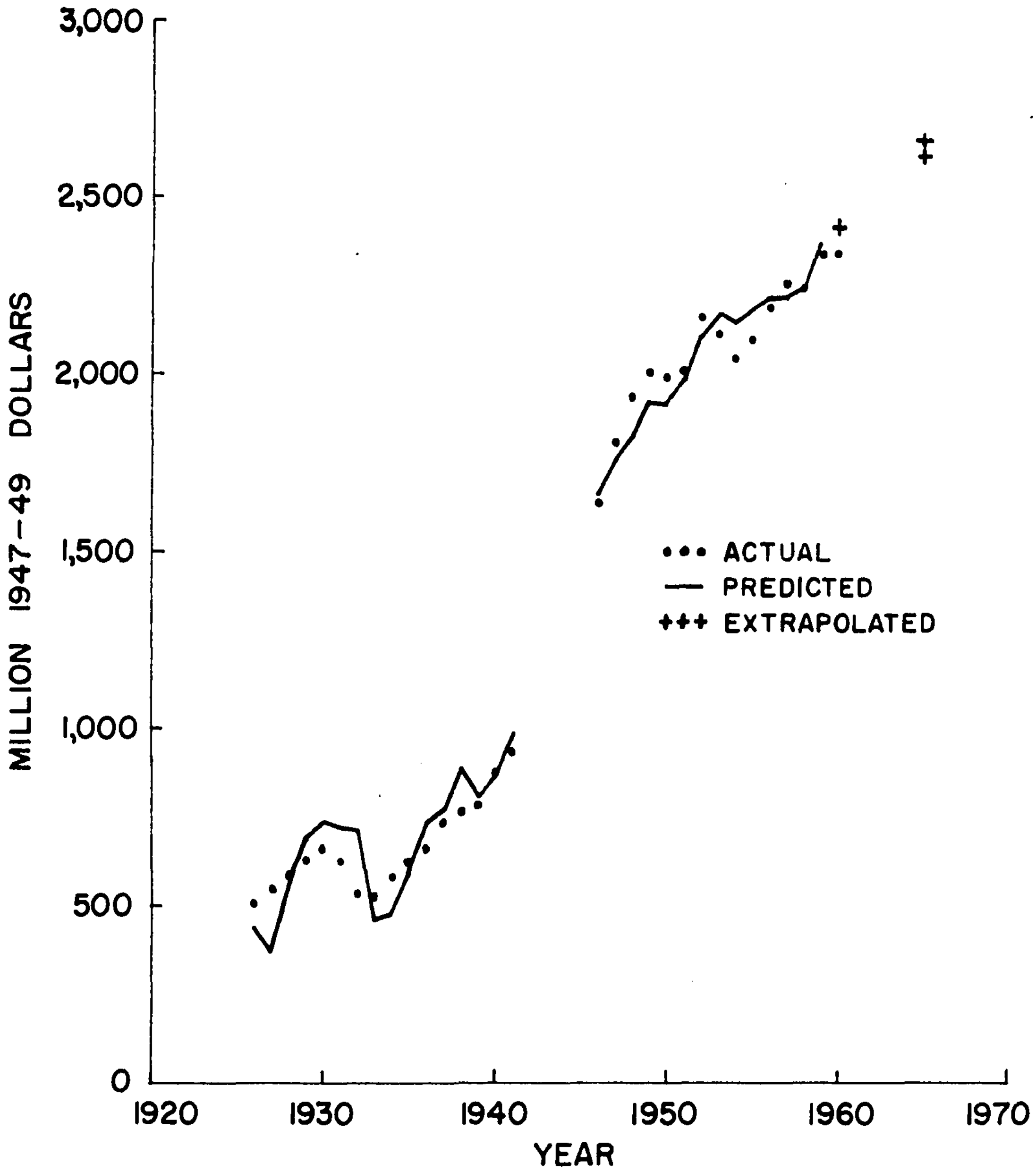

Figure 3. Trends in purchases of machinery supplies Q_{MS} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 13-0

a linear extension of the postwar trend. Of course, the validity of the projections are subject to conformity with the underlying assumptions of the model.

Demand for Purchased Feeds

Feed purchases, measured in constant 1947-49 dollars, increased 218 percent from 1926 to 1959. The compound rate of growth was 3.6 percent per year. In this study, feed purchases include feed grains and protein feeds. Many of the components of operating inputs such as fertilizer and motor supplies are produced completely by the non-farm sector. Feeds, and to some extent seeds, even when purchased from non-farm sources usually contain important ingredients produced on farms. It is not surprising, therefore, to observe that the index of the ratio of prices paid for feed to prices received by farmers for crops and livestock has been quite stable since 1926. The index in 1926 was 98.9 and in 1959 was 97.4. The ratio of prices paid for feed to prices received for livestock displays a similar lack of trend, but annual variations in the series provide a basis for appraising the effects of prices on demand quantities of feed.

Hildreth and Jarret estimated the demand for feed grains by single and simultaneous equations (61). They specified the following variables in the demand equations: the quantity of feed grains fed, feed grain price, livestock price, protein price, beginning year animal units of livestock, and roughage consumed by livestock. In the single equations, the quantity of feed grains fed to livestock was the dependent variable. Additional details of their study including elasticity estimates are discussed later in this section.

Specification of the demand function

In this study, the quantity demanded of feed by farmers is estimated as a function of feed prices, livestock prices, prices paid by farmers, stocks of productive assets, government policies, weather and time. The specification is somewhat similar to that of Hildreth and Jarret except prices paid P_P are included rather than protein prices, and inventories of productive assets are substituted for livestock inventories. The model in this study contains no estimate of roughage consumption, but contains variables G, W and T representing the influence of institutions, weather and technology on feed demand. S_p is highly correlated with livestock inventories ($r = 0.91$), thus the coefficient of S_p broadly may be interpreted as the effect of livestock inventories as well as other assets on feed demand.

The exact form and sources of the variables in the feed demand function are as follows:

Q_{Fdt} The dependent variable is the purchases of feed by the U.S. farmers during the current calendar year in millions of 1947-49 dollars (120, 121). The "quantity" is derived by dividing expenditure data by prices paid by farmers for feed. Inter-farm sales are included. The estimate includes protein and feed grain purchases.

$(P_{Fd}/P_R)_t$ The current year index of the ratio of prices paid by farmers for feed to prices received by farmers for crops and livestock (120). Both current and past year prices are included in the demand function.

$(P_{Fd}/P_{Lk})_t$ The current year index of the ratio of prices paid by farmers for feed to prices received by farmers for livestock (120). The past year index is also included in the demand function.

$(P_{Fd}/P_P)_{t-1}$ The past year index of the ratio of prices paid by farmers for feed to prices paid by farmers for items used in production, interest, taxes and wage rates (120).

Productive assets S_p, an index of government programs G, weather W and a time variable T also are included in the demand function. The sources and logic of these variables are discussed in more detail in the section on fertilizer demand. All equations are estimated with annual data from 1926 to 1959, excluding the war years.

The estimated demand equations

The independent variables in equations 17 and 18 of Table 4 explain a large proportion ($\bar{R}^2 = 0.97$) of the annual variation about the mean of Q_{Fdt}. Current and past prices, stocks of productive assets and time primarily are responsible for the high $\bar{R}^2$. Coefficients of G, W and P_{Fd}/P_P are not significant in equations 17 and 18. Insignificance of the coefficients is not certain evidence that the effects the variables are intended to represent do not influence demand. The results only indicate that given the form of the variables, coefficients of the magnitudes indicated occur frequently when the true coefficients are zero. Other variables representing the same influences but constructed differently might exert a significant influence on feed demand.

Because the demand for feed primarily is derived from the demand for livestock, P_{Lk} is substituted for P_R in the remaining equations in Table 4. Equation 19 is the result of this substitution and the deleting of insignificant variables from equations 17 and 18. The coefficients of current and lagged price P_{Fd}/P_{Lk} are less significant in equation 19 than are comparable coefficients of P_{Fd}/P_R in equation 17. Based on the results in equation 20, the significance of current and lagged price variables is inconclusive. The time coefficient appears to dominate the S_p coefficient in equations 19-L and 19-F. The instability of the coefficients of S_p and T may be

Table 4. Demand functions for feed Q_{Fd} estimated by least squares with annual data 1942 to 1945; coefficients, standard errors (in parenthesis) and related s

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_{Fd}/P_R t	P_{Fd}/P_R t-1	P_{Fd}/P_{Lk} t	P_{Fd}/P_{Lk} t-1	P_F
17-0	0.98	1.05	800.06	-18.78	-27.10			
	0.97			(8.67)	(8.37)			
18-0	0.98	1.02	2117.02	-24.10	-25.80			-3
	0.97			(8.13)	(8.52)			(5
19-0	0.96	0.75	-3809.35			-11.09	-8.94	
	0.95					(5.03)	(5.20)	
19-L	0.94	0.71	2.56			-0.62	-0.70	
	0.93					(0.29)	(0.30)	
19-F	0.21	1.50	--[d]			-2.34	-8.48	
	0.12					(3.27)	(3.31)	
20-0	0.98	1.74	119.46		-3.39	-3.20		
	0.98				(3.60)	(3.74)		
20-L	0.97	1.68	2.16		-0.23	-0.37		
	0.97				(0.20)	(0.21)		
21-0	0.98	1.73	-144.15			-4.19		
	0.98					(3.58)		
21-L	0.97	1.65	1.73			-0.43		
	0.97					(0.20)		

[a]Sources and composition of the dependent variable Q_{Fd} and the indicated indepe

[b]Equations are estimated in the transformations indicated: original values 0,
and first differences of original values F.

[c]The Durbin-Watson autocorrelation statistic d'.

[d]The intercept or constant coefficient in the first difference equation is comp
The standard error of the coefficient was not computed.

with annual data from 1926 to 1959, omitting
sis) and related statistics are included[a]

$/P_{Lk}$ t	P_{Fd}/P_{Lk} t-1	P_{Fd}/P_p t-1	S_p t	G t	W t	T	Q_{Fd} t-1
			39.53	-7.33	3.57	70.79	
			(15.75)	(7.08)	(4.64)	(12.53)	
		-3.23	35.66	-7.19		73.18	
		(5.47)	(17.15)	(7.28)		(13.10)	
.09	-8.94		70.27			57.03	
.03)	(5.20)		(16.80)			(14.21)	
.62	-0.70		1.55			0.0116	
.29)	(0.30)		(0.75)			(0.0029)	
.34	-8.48		-14.14			94.03	
.27)	(3.31)		(38.62)			--[d]	
.20						31.02	0.765
.74)						(10.82)	(0.096)
.37						0.0065	0.64
.21)						(0.0019)	(0.10)
.19						29.63	0.788
.58)						(10.69)	(0.092)
.43						0.0062	0.674
.20)						(0.0019)	(0.099)

: indicated independent variables are discussed in the text.

'iginal values O, logarithms L (T is in original values in L equations),

: equation is comparable to the coefficient of T in the O and L equations.

the result of the correlation between the two variables, and indicates that their coefficients should be interpreted collectively. The Durbin-Watson statistic indicates significant autocorrelation in the residuals of equations 19-O and 19-L.

To reduce the autocorrelation in the residuals and to provide more nearly consistent statistical tests of the coefficients, equation 19 is estimated in first differences of original values. The d' is raised from 0.75 in equation 19-O to 1.50 in equation 19-F. The degree of autocorrelation in the residuals as indicated by d' is reduced somewhat, but the test of the null hypothesis of zero autocorrelation is on the borderline between insignificant and inconclusive. The drop in the R^2 from 0.95 in equation 19-O to 0.12 in equation 19-F indicates that a very large proportion of the variance around the mean of Q_{Fr} is explained by linear trends removed by the first difference transformation. The instability of the coefficients of S_p and T in equation 19 may be explained by the high correlation between the variables ($r = 0.92$). Because of the expected complementary relationship between durable inventories and Q_{Fd}, the significant positive coefficient of S_p in equation 19-O is most meaningful.

The magnitudes of the coefficients in the distributed lag equations 20 and 21 are not consistent with the coefficients in previous conventional models. When a strong complementarity is expected to exist between an operating input such as feed and a durable asset such as livestock, there is some doubt about the validity of a distributed lag model of the form indicated in equation 20 and 21. The coefficient of the lagged quantity variable was insignificant in feed equations including durable assets. The implication is that there is no long run adjustment of feed purchases, given the level of stock. In the long run, as inventories of livestock and other assets are changed, feed purchases also change. If this reasoning is accepted, equations such as 17, 18 and 19 are more appropriate expressions of feed demand than are equations 20 and 21.

The price coefficients in equations 20 and 21 are insignificant. An exception is the coefficient of $(P_{Fd}/P_{Lk})_{t-1}$ which is significant at the 95 percent probability level in equation 21-L. The coefficients of the lagged quantity and time are significant in the distributed lag equations. The results indicate that approximately one-fourth of the adjustment to the equilibrium or desired level of feed purchases is made in the short run. Whether the result can be taken seriously without specifically including complementary inventories such as livestock in the equation is subject to doubt.

Price elasticity of demand

The total demand elasticity with respect to current and past year feed prices estimated from equations 19-O and 19-L are respectively -0.8 and -1.3. Since price ratios are employed, the elasticity with respect to livestock prices are the same values but with positive algebraic signs. Because the reliability of the data from which the demand equations are generated is questionable, it is desirable to consider the estimated elasticities as hypotheses suitable for further testing rather than as accurate and final coefficients. It is notable, however, that these estimates conform closely with the results of the study by Hildreth and Jarrett (61). Their average estimates from single and simultaneous equations of the demand elasticity of feed grains with respect to livestock prices was 1.1 and with respect to feed prices was -0.8.

The estimated demand elasticity with respect to S_p from equation 19-O is 2.3; from equation 19-L is 1.6. A comparable statistic from Hildreth and Jarrett, the elasticity of demand for feed grains with respect to livestock inventories (an average of several estimates), was 1.6.

The techniques of this study are not suited for estimating the responsiveness of feed purchases to changes in cattle prices through the inventory effect. A more fundamental explanation of the responsiveness of feed demand to long run changes in farm product prices through S_p is available. If a sustained one percent increase in P_R increases S_p one percent, then feed inventories will be increased from one to two percent according to equations 19-0 and 19-L. Because the data and procedures are somewhat crude, no attempt is made to evaluate the exact long run elasticity with respect to P_R. It is expected, however, that a sustained one percent increase in product prices would increase feed purchases more than two percent in the long run.

Shifts in demand

On the basis of equation 19-0, if prices had been at 1959 levels in 1926, the quantity demanded of feed would have been approximately 12 percent greater than the predicted quantity in 1926. Thus, nearly 200 of the total 218 percent increase in demand from 1926 to 1959 remains to be explained by factors other than short run price changes.

Several factors other than short run price changes have tended to increase demand for the two major components of feed purchases -- high protein concentrates and feed grains. Improvements in the nutritive content of protein feeds may be defined as an improvement in feed quality or as a decrease in real cost per nutrient unit of feed. However defined, improvements in the vitamin, mineral, protein and other contents of "balancer" feeds coupled with greater knowledge by farmers of these improvements, undoubtedly has been an important element in increasing sales. Both commercial and public interests have assumed an important role in improvement of livestock rations and dissemination of management aid to farmers.

Large increases in feed grain purchases, the second major component of total feed purchases, have also occurred since 1926. The rise in purchases reflects the tendency toward specialization in production of agricultural commodities. For example, a Midwest or Great Plains farmer, who formerly produced both feed and livestock, now raises grains only. The grain eventually arrives in the East where it is purchased by a farmer specializing in broiler production. As farming becomes more specialized, the proportion of purchased inputs tends to rise.

Trends and projections

Figure 4 depicts a decreasing trend in feed purchases from 1926 to 1935. After 1935, a general upward trend in purchases is apparent, despite occasional short term reversals. There are no signs of a reversal of the strong upward trend in recent years.

Some doubt exists about the structural pertinence of distributed lag equation 21-0. Its high predictive power ($\bar{R}^2 = 0.98$) and absence of current price recommend it for predictive purposes. Some autocorrelation in the residuals of the conventional equations seems to be absorbed into the coefficients of the distributed lag equation 21-0. This

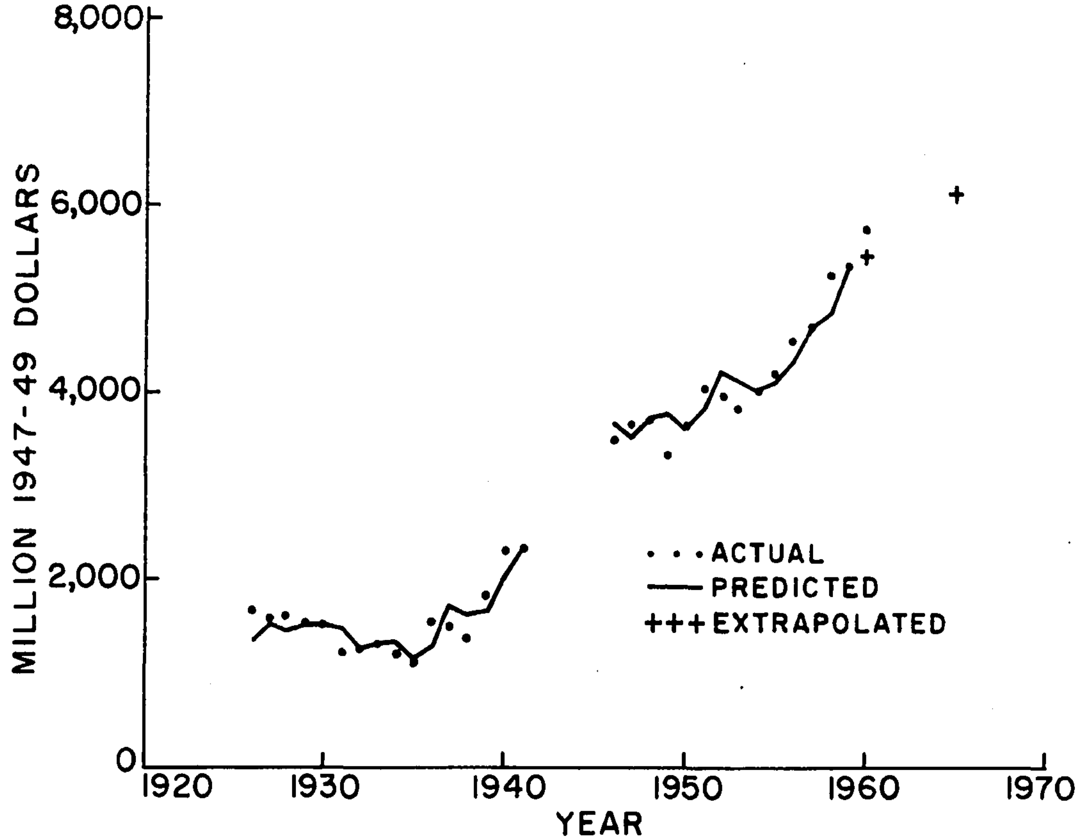

Figure 4. Trends in purchases of feed Q_{Fd} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 21-0

autocorrelation may be due to systematic errors in the data or failure to specify variables which account for the cattle cycle. For predictive purposes, we need not be greatly concerned about the structural validity of the coefficients but rather with the fit of the equation to the actual observations.

Equation 21-0 predicts the data quite well when the quantity changes slowly from year to year. The equation does not accurately indicate more violent changes in quantities such as occurred in the early 1950's, however. The extrapolated estimate of feed purchases for 1960 is six percent below actual purchases.

Projections from the equation indicate that purchases will increase 12 percent above predicted 1960 estimates by 1965. That is, feed purchases are expected to increase approximately two percent per year according to equation 21-0. The projection is based on the assumption that prices will remain at 1955-59 levels, and that the structural relationship indicated by equation 21-0 remains appropriate. A linear extension of the trend in feed purchases from 1955 to 1960 would result in a much larger projected increase in feed purchases. It appears that the estimate from equation 21-0 is conservative. It also should be mentioned that the analysis is highly aggregative, and purchases of some components of feed are expected to increase at greater rates.

Demand for Building Repairs

The USDA classifies expenditures on fences, windmills, wells and buildings other than the operator's dwelling under two categories -- repairs and improvements. Building improvements include new construction, additions and major improvements and are classified as durable goods or investment in this study. Building repairs, inputs necessary to maintain the usefulness and productivity of buildings, fences, etc., have certain characteristics relating to the definition of operating inputs. A large number of these repairs are a function of the level of farm output. Hence, building repairs are classified as operating inputs, although some components of repairs, undoubtedly, do not fall into this classification.

Purchases of building repairs, measured in 1947-49 dollars, dropped from 424 million in 1926 to 345 million in 1959. This was a drop in inputs of building repairs of 19 percent during the 33 year period, a compound rate of 0.6 percent per year. The declining trend in purchases of building repairs is a real contrast to the growth in purchases of aggregate operating inputs at an average annual compound rate of 3.6 percent.

Specification of the demand function

To analyze some of the forces responsible for falling demand for building repairs, it is appropriate to consider the demand structure. The demand quantity is a function of prices of building and fence materials, prices received by farmers, prices paid by farmers, beginning year stocks of buildings, beginning year stocks of productive assets, government programs, weather and slowly changing forces represented by the time variable. Stocks of buildings were not available when the statistical demand equations were computed. Later, an approximate estimate of building inventories was constructed. Since this estimate correlates highly ($r = 0.92$) with stocks of productive assets, only the latter is included in the demand functions. The variables are defined in more detail as follows:

Q_{BRt} The dependent variable is the purchases of building repairs by U.S. farmers during the current calendar year in millions of 1947-49 dollars (4). The estimate includes repairs on fences, windmills, wells and farm buildings other than the operator's dwelling.

$(P_B/P_R)_t$ The current year index of the ratio of prices paid by farmers for building materials to the ratio of prices received by farmers for crops and livestock (120). Current and past year prices are included in the demand function.

$(P_B/P_P)_{t-1}$ The past year index of the ratio of prices paid by farmers for building materials to prices paid by farmers for items used in production, including interest, taxes and wage rates (120). The simple correlation between current and past year values is 0.92, hence, only past year values are included in the demand function.

In addition to these price variables, the demand quantity is specified as a function of the beginning year stocks of productive assets S_p, an index of government programs G, weather W and time T. The sources and logic of these variables is discussed in more detail in the section on fertilizer demand. All functions are estimated from aggregate annual data for the years 1926 to 1959, omitting 1942 to 1945.

The estimated demand equations

In Table 5, the demand quantity of building repairs Q_{BR} is depicted as a function of the variables indicated. The coefficient of G is not significant in equation 22, therefore, the variable is omitted in equation 23. The coefficient of the current price P_B/P_R is low and insignificant in equation 26 -- the past price ratio is dominant. Beginning year stocks of productive assets appear to have little influence on Q_{BR}. The insignificant coefficient could be caused by conflicting effects on Q_{BR} of variables correlated with S_p. Examples of these variables are: (a) inventories of buildings, (b) stocks of cash and other assets held for production, (c) farm size,

Table 5. Demand functions for building repairs Q_{BR} estimated by l
1926 to 1959, omitting 1942 to 1945; coefficients, stanc
related statistics are included[a]

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_B/P_R t	P_B/P_R t-1	P_B/P_P t-1
22-O	0.57 0.43	1.00	237.90	-0.42 (0.87)	-2.89 (1.06)	7.56 (3.22)
23-O	0.56 0.45	1.02	169.57	-0.37 (0.85)	-2.84 (1.03)	8.28 (2.67)
23-L	0.56 0.45	1.01	-0.81	-0.21 (0.31)	-0.98 (0.37)	2.49 (0.76)
24-O	0.56 0.51	1.03	213.49		-3.23 (0.59)	8.56 (2.36)
24-L	0.54 0.48	1.00	0.42		-1.16 (0.22)	2.46 (0.67)
24-F	0.30 0.23	2.42	--[d]		-2.48 (0.78)	4.16 (2.83)
25-O	0.70 0.64	1.91	79.21		-2.35 (0.56)	6.51 (2.09)
25-L	0.68 0.63	1.95	-0.097		-0.88 (0.20)	1.90 (0.59)

[a]Sources and composition of the dependent variable Q_{BR} and the
discussed in the text.

[b]Equations are estimated in the transformations indicated: ori
original values in L equations), and first differences of original v

[c]The Durbin-Watson autocorrelation statistic d'.

[d]The intercept or constant coefficient in the first difference
of T in the O and L equations. The standard error of the coefficien

estimated by least squares with annual data from
icients, standard errors (in parenthesis) and

$_B/P_R$ t-1	P_B/P_P t-1	S_p t	G t	W t	T	Q_{BR} t-1
.89	7.56	0.20	-0.82	0.37	-5.75	
.06)	(3.22)	(3.37)	(1.99)	(0.98)	(4.48)	
.84	8.28	0.52		0.40	-6.91	
.03)	(2.67)	(3.22)		(0.95)	(3.43)	
.98	2.49	0.53		0.15	-0.0098	
.37)	(0.76)	(0.88)		(0.25)	(0.0046)	
.23	8.56				-6.55	
.59)	(2.36)				(1.76)	
.16	2.46				-0.0075	
.22)	(0.67)				(0.0022)	
.48	4.16				2.61	
.78)	(2.83)				--d	
.35	6.51				-4.69	0.40
.56)	(2.09)				(1.59)	(0.12)
.88	1.90				-0.0055	0.37
.20)	(0.59)				(0.0019)	(0.11)

.e Q_{BR} and the indicated independent variables are

ndicated: original values O, logarithms L (T is in
of original values F.

st difference equation is comparable to the coefficient
the coefficient was not computed.

and (d) structural changes in product demand, specialization and production techniques. Greater investment in buildings may tend to increase demand repairs, but if the new investment replaces old buildings, repair costs are reduced. Cash for productive purposes and other assets may increase demand for building repairs, but shifts in demand from butter to margarine and improved methods of storing hay (bales) may decrease demand. The influence of each of these correlated variables may be significant, but the collective effect is zero in S_p. Undoubtedly, some of these influences are reflected in the significant coefficient of the time variable. Weather, at least in the form indicated by W, does not influence significantly the demand quantity. Only the variables with significant coefficients in equation 23 are retained to form equation 24.

Although all coefficients are significant in equation 24, the three variables explain only one-half of the variation about the mean of Q_{BR}. A linear time trend in purchases of building repairs is not as apparent as the time trend in purchases of other inputs previously discussed. Much of the $\bar{R}^2$ in previous demand equations resulted from the time trend, and exaggerated the ability of the equations to predict annual variations in data.

The d' statistic indicates significant autocorrelation of the residuals at the 95 percent probability level in equations 24-O and 24-L. The Durbin-Watson test suggests that the first difference transformation successfully eliminates the significant autocorrelation. The coefficient of P_B/P_P after the transformation, which is expected to provide a more accurate estimate of the significance of the coefficients, is insignificant. This casts some doubt on the validity of the complementarity of building repairs with other inputs implied by the significant positive coefficients of P_B/P_P in equations 24-O and 24-L. The coefficient of T is 2.61 in equation 26-F, and indicates that after adjustments for prices, the demand for building repairs has increased during the years 1926 to 1959. Although the coefficient was not tested statistically, it is probably not significantly different from zero. In this respect, the coefficient of time in equation 24-F agrees with the results of equations 22 and 23-O, i.e., the coefficients of time are not significant.

The statistical fit is improved considerably by including lagged Q_{BR} as an independent variable (equation 25). Although the magnitudes of the price coefficients are reduced from equation 24, all coefficients in equation 24 are significant. The variables explain 63 percent or more of the annual variation about the mean of Q_{BR}. Autocorrelation is insignificant in the equation, but it must be remembered that the d' statistic tends to underestimate the degree of autocorrelation in such equations. Although equation 24 is structurally suspect because of failure to account for building inventories, the equation is useful for predictive purposes.

Price elasticity of demand

The price elasticities of demand for building repairs with respect to $(P_B/P_R)_{t-1}$ in equations 24-0 and 24-L, respectively are -1.02 and -1.16. The estimates indicate that a one percent increase in prices received by farmers is associated with a one percent increase in purchases of building repairs in the short run. Equation 25 indicates that a major portion, approximately 60 percent, of the adjustment of purchases to price changes is made in the short run. The long run elasticity computed with respect to $(P_B / P_R)_{t-1}$ is -1.23 from equation 25-0, and -1.40 from equation 25-L. The long run elasticities are not much larger than the short run elasticities. This result is substantiated by the insignificance of the coefficients of S_p in equations 22 and 23.

The price elasticity of demand with respect to $(P_B/P_P)_{t-1}$ estimated from equation 24-0 is 2.18; from equation 24-L is 2.46. The results indicate building repairs are complements of other inputs in the market. A one percent drop in the prices paid for agricultural inputs is expected to increase purchases of building repairs approximately two percent. As indicated previously, the magnitude of the elasticity of demand with respect to $(P_B/P_P)_{t-1}$ is somewhat questionable.

The total elasticity of demand with respect to P_B from equation 24-L is 1.3 (-1.16 due to the change in price relative to P_R plus 2.46 due to the change in price relative to P_P). If the complementarity effect is negligible as indicated by equation 24-F, then the elasticity of demand with respect to P_B is approximately -1.0.

Shifts in demand

Unlike other operating inputs, the demand quantity Q_{BR} has declined at an average compound rate of -0.6 percent per year from 1926 to 1959. The demand for building repairs has displayed no large shifts such as characterized demand for other groups of operating inputs. Had prices been at 1959 levels in 1926, the demand quantity would have been approximately 15 percent above actual 1926 levels according to equation 24-O. The implication is that the demand curve has remained quite stable or shifted downward slightly during the 33 year period.

Forces influencing demand have not remained constant, and the relatively stable demand may be the result of opposing forces offsetting each other. *Ceteris paribus*, the increasing output of agriculture requires more operating inputs. But more efficient use of resources, shifts in consumer demand and other structural changes reduce requirements for some resources.

Purchases of repairs was not commensurate with the increased investment in farm buildings of approximately 30 percent from 1926 to 1959. The necessity for purchasing additional repair for these buildings is offset by other forces operating to reduce the demand for building repairs. For example, because of shifts in consumer demand from butter to margarine, a large investment in dairy barns and equipment is obsolete. Other forces depressing demand for building repairs are decreases in the number of farms, development of more durable and flexible construction materials, and adoption of farm practices which reduce building repair needs. Consolidation of farm units often makes the second set of buildings of little use. The marginal value product of obsolete buildings is sometimes greatest when used as repairs for other buildings. Such repairs are not included in Q_{BR}, the measure used in this report. The substitution of durable items such as bricks or blocks for wood in construction also lessens the need for repairs. Finally, baling hay, storing shelled corn in steel bins, and other changes in farm practices tend to reduce demand for building repairs.

<u>Trends and projections</u>

A highly volatile trend in purchases of building repairs is depicted in Figure 5. Inputs of building repairs fell sharply during the depression years but recovered to the high

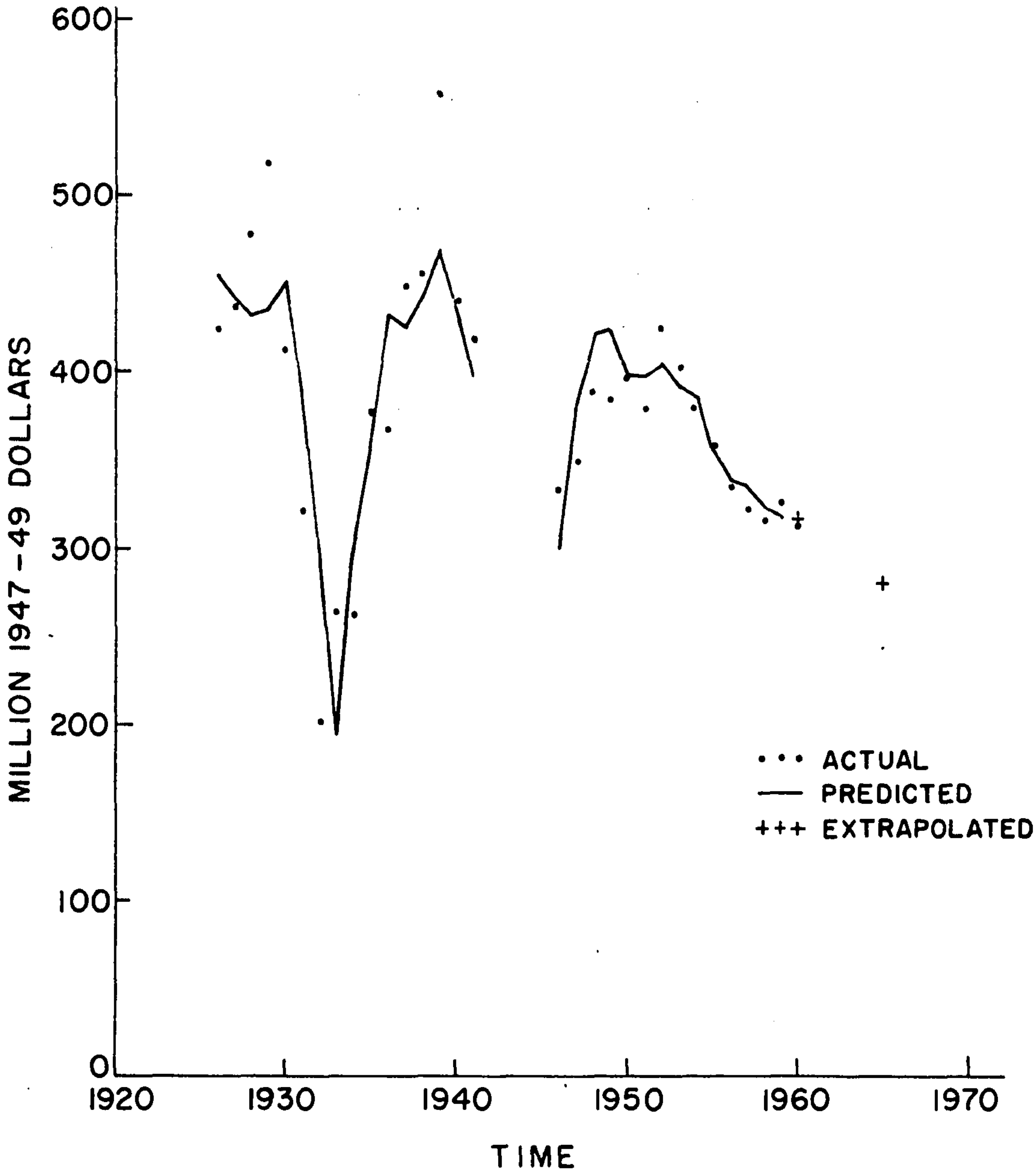

Figure 5. Trends in purchases of building repairs Q_{BR} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 25-0

pre-depression level after 1926. Sales made a rapid recovery after World War II until 1948, then leveled off and finally began a gradual, somewhat regular decline after 1952. A secular trend is not apparent except perhaps after 1948. The large fluctuations in quantities during the early years may partially be because of errors in the data.

Quantities estimated by the distributed lag equation 25-0 fit the observed values reasonably well in the postwar period. The extrapolated value Q_{BR} from the equation for 1960 is 317 million 1947-49 dollars. The actual 1960 purchases, 311 million 1947-49 dollars, are overestimated by only two percent. Assuming average 1955-59 prices, and that the structural relationship embodied in equation 25-0 are relevant until 1965, the projected 1965 quantity is 277 million 1947-49 dollars. The projected quantity is approximately 12 percent below the predicted 1960 quantity. Examination of the recent tendency for the decline beginning in 1948 to level off, suggests that this projection may be overly pessimistic. Recent structural changes causing demand to fall less sharply may not be adequately represented in equation 25-0 because of the limited number of observations for the latest years.

Demand for Miscellaneous Operating Inputs

Minor operating inputs not included in the previous categories are classified as miscellaneous inputs. The category contains such heterogenous items as repairs by blacksmiths, expenditures for small hand tools and other hardware items, fire, crop and hail insurance, greenhouse and nursery supplies, binding materials, veterinary services and medicine, telephone, dairy supplies, livestock marketing services, and milk hauling. Some of the items are not closely related to output but are fixed expenses or investments in minor durable items. The major portion of these inputs, however, falls within the definition of operating inputs discussed earlier. Since expenditures are not available by individual items, the entire grouping is conveniently classified and discussed within the framework of operating inputs.

Inputs of miscellaneous items increased 85 percent from 1926 to 1959, or at an average compound rate of 1.8 percent per year. During the same period inputs of all agricultural resources increased only at the rate of 0.2 percent per year or a total of only 5.5 percent. Hence, there was a net substitution of miscellaneous inputs for other inputs in the production process. It is useful to examine the demand function for miscellaneous inputs to determine some of the forces responsible for the growing use of miscellaneous items by farmers.

Specification of the demand function

The quantity purchased is estimated as a function of current and past prices of miscellaneous items, price received and prices paid by farmers, inventories of productive assets, weather, government programs and slowly changing forces reflected by a time variable. Decisions to buy miscellaneous inputs are assumed to depend on current and past year prices. Many of the items contained in the aggregate are a function of fixed resource levels as well as prices. Thus, the stock of productive assets is specified in the demand function to reflect changes in scale or plant size. Complementarity is anticipated between asset levels and purchases of miscellaneous items. The variables in the demand function are as follows:

$Q_{MI\,t}$ — The dependent variable is purchases of miscellaneous operating inputs by U.S. farmers during the current calendar year in millions of 1947-49 dollars (4).

$(P_{MI}/P_R)_t$ — The current year index of the ratio of prices paid by farmers for miscellaneous operating inputs (farm supplies) to the ratio of prices received by farmers for crops and livestock (120). Current and past year prices are included in the demand function.

$(P_{MI}/P_P)_{t-1}$ — The past year index of the ratio of prices paid by farmers for miscellaneous inputs to prices paid by farmers for items used in production including interest, taxes and wage rates (120). Since the simple correlation between current and past prices is high ($r = 0.93$), only past prices are included in the production function.

Additional variables specified in the demand function are the stock of productive assets S_p, an index of government programs G, a weather variable W and time T. The sources and structure of these variables are discussed in more detail in the section on fertilizer demand. All variables are aggregate estimates for the U.S. from 1926 to 1959, omitting 1942 to 1945.

The estimated demand equations

Table 6 includes five empirical demand functions for miscellaneous operating items estimated by least squares from the foregoing data. The institutional variable appears to have little influence on demand, and is dropped from equation 26 to form equation 27. The coefficients of past year prices in the equation 27 are of low significance. This need not mean that past year prices are unimportant. The current year price P_{MI}/P_R may be a "stronger" variable than the past value, and tend to absorb the influence of the latter. For predictive purposes, and to observe the influence of dropping the current price variable, equation 28 is estimated with lagged P_{MI}/P_R, S_p, W and T. The coefficients of lagged price and weather are significant at the 90 percent level in the logarithm equation 28-L. Since 99 percent of the annual variation about the mean of Q_{MI} is explained by the four independent variables in equation 28, it is useful for predictive

Table 6. Demand functions for miscellaneous operating inputs Q_{MI} es
1926 to 1959, omitting 1942 to 1945; coefficients, standar
are included[a]

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_{MI}/P_R t	P_{MI}/P_R t-1	P_{MI}/P t-1
26-O	0.99	1.90	-1689.76	-0.44	0.056	0.13
	0.99			(0.36)	(0.557)	(2.43
27-O	0.99	1.88	-1731.77	-0.45	0.16	0.19
	0.99			(0.35)	(0.53)	(2.40
27-L	0.99	1.85	-1.62	-0.067	-0.018	0.07
	0.99			(0.050)	(0.081)	(0.26
28-O	0.99	1.98	-1686.99		-0.17	
	0.99				(0.21)	
28-L	0.99	2.03	-1.34		-0.057	
	0.99				(0.028)	
29-O	0.99	1.93	-1674.40	-0.30		
	0.99			(0.21)		
29-L	0.99	1.82	-1.41	-0.070		
	0.99			(0.027)		
29-F	0.37	2.53	--[d]	-0.62		
	0.29			(0.43)		
30-O	0.98	2.55	46.59	-0.43		
	0.98			(0.29)		
30-L	0.98	2.73	0.52	-0.074		
	0.98			(0.037)		

[a]Sources and composition of the dependent variable Q_{MI} and the
the text.

[b]Equations are estimated in the transformations indicated: ori
values in L equations), and first differences of original values F.

[c]The Durbin-Watson autocorrelation statistic d'.

[d]The intercept or constant coefficient in the first difference
in the O and L equations. The standard error of the coefficient was

inputs Q_{MI} estimated by least squares with annual data from
ents, standard errors (in parenthesis) and related statistics

$_I/P_R$ t-1	P_{MI}/P_P t-1	S_p t	G t	W t	T	Q_{MI} t-1
.056	0.13	29.96	-0.59	1.16	0.81	
.557)	(2.43)	(2.99)	(0.84)	(0.59)	(1.81)	
.16	0.19	30.32		1.20	0.44	
.53)	(2.40)	(2.91)		(0.58)	(1.71)	
.018	0.070	2.30		0.097	0.00043	
.081)	(0.265)	(0.26)		(0.046)	(0.00068)	
.17		29.70		1.07	1.10	
.21)		(1.80)		(0.56)	(1.53)	
.057		2.20		0.090	0.00077	
.028)		(0.15)		(0.046)	(0.00059)	
		29.93		1.11	0.64	
		(1.74)		(0.53)	(1.53)	
		2.24		0.097	0.00050	
		(0.14)		(0.043)	(0.00059)	
		28.01		1.29	2.51	
		(8.12)		(0.59)	--[d]	
					3.71	0.892
					(2.03)	(0.075)
					0.00140	0.864
					(0.00076)	(0.076)

Q_{MI} and the indicated independent variables are discussed in

ndicated: original values O, logarithms L (T is in original
al values F.

t difference equation is comparable to the coefficient of T
efficient was not computed.

purposes. However, the coefficients of current price in equation 29 are larger in absolute terms and more significant than in equation 28. Coefficients of all variables, except T in equation 29-L, are significant at the 95 percent level. The d' statistic indicates that autocorrelation is insignificant in equations 29-O and 29-L.

Equation 29-F, a first difference transformation from original values, is included to aid in interpreting the price coefficients. That the magnitudes of the price coefficients in equation 29-F and 29-L are comparable is evident from the respective estimates -0.08 and -0.07 of the price elasticity of demand.

The coefficient of the stock of productive assets S_p is highly significant in equations 26 to 29. The trend in the variable is somewhat related to the time variable and may tend to reflect some of the influences usually associated with T since the coefficient of T is not significant. The inclusion of S_p is intended to make the equations short run. As with other operating inputs, the coefficient of a lagged dependent variable added to equation 29 is not significant. (These equations including S_p and Q_{MIt-1} are not included in Table 6.) The implication is that there is little influence of lagged prices P_{MIt-1} and other influences represented by Q_{MIt-1} on current demand quantities if the scale of plant is fixed.

Equation 30 is estimated with S_p excluded as an approximate indication of demand when the agricultural plant size is allowed to vary. The short run price coefficients in the equation are similar in magnitude to the estimates in equation 29. The distributed lag equation 30 indicates that adjustments of purchases to price changes occurs slowly -- only approximately 13 percent in the short run. Weather, which appeared to be of some importance in explaining demand for Q_{MI} in equations 26 to 29, is not included in equation 30.

Price elasticity of demand

The point estimate and 95 percent confidence interval of the short run price elasticity of demand for Q_{MI} with respect to P_{MI} computed from equation 29-L is -0.070 ± 0.056. The short run elasticity with respect to P_R is the same magnitude but positive in sign. The results indicate that the short run demand for miscellaneous inputs is highly inelastic. A ten percent fall in P_{MI} could be expected to increase purchases less than one percent. The low price elasticity of demand for miscellaneous inputs may be explained by: (a) the minor importance of the individual components of the inputs in the farm budget, (b) the fact that some components of Q_{MI} are related to family living as well as production, and (c) a strong complementarity of miscellaneous inputs with fixed assets which are relatively unresponsive to short run price changes. Electricity and the telephone, for example, are closely related to family living expenses as well as production, and their use is often unresponsive to price changes. Insurance also tends to remain a relatively stable "quantity" in the short run despite changes in the price of insurance. Expenditures for such items tend to remain at fixed levels if any production takes place.

The long run elasticity of miscellaneous inputs with respect to P_R is found from the relationship between Q_{MI} and S_p in demand equation 29. Each of the three forms of the equation indicates that a one percent increase in S_p is associated with a 2.2 to 2.4 percent increase in Q_{MI}. In Table 6, Chapter 9, empirical analysis indicates that the elasticity of S_p with respect to P_R approximately is unitary in the long run. The implication is that a sustained one percent rise in farm product prices potentially may increase demand for miscellaneous inputs more than two percent. Despite the inelastic response of miscellaneous inputs to short run prices, the response in the long run may be very large. This arises from the strong complementarity of miscellaneous inputs with farm productive assets. Two comments should be added. First, the long run probably is more than 20 years. Second, the correlation of S_p with technological and other gradual changes in farming may impart positive bias to the coefficient of S_p.

Shifts in demand

Only a small portion (three percent) of the 83 percent increase in purchases of miscellaneous operating inputs from 1926 to 1959 is explained by short term price changes. Interpreted literally, the insignificant coefficient of T in equation 29 would indicate that there have been no shifts in demand for Q_{MI} that cannot be explained by the requirement to service the growing agricultural plant S_p. Technological changes have occurred, however, and the effect partially is reflected in the coefficient of S_p. Technological changes which occur and are adopted at a slowly changing rate may correlate more closely with S_p than T, hence the effects are registered in the coefficient of the productive assets variable. It seems reasonable to conclude that technological forces may not have increased demand for miscellaneous inputs as much as for other categories of operating inputs. Innovations sometimes decrease demand for certain inputs, and this tendency is evident in several components of Q_{MI}. Examples are blacksmith repairs (declining demand for horseshoeing), binder twine (grain binders replaced by combines) and dairy supplies (less butter production).

Trends and projections

The general trend in purchases of miscellaneous inputs has been similar to that found previously for other categories of operating inputs (Figure 6). Purchases dropped slightly during the depression. Following the depression, purchases began an upward trend which persisted except for some short run interruptions until 1960. Equation 28-0 predicts the actual observations quite well throughout the 33 year period. The extrapolation to 1960 from the equation overestimated the actual observation by less than one percent. Since equation 28-0 does not contain current prices, the prediction is made from past values of P_{MI}/P_R, S_p and from T. Projections of Q_{MI} for 1965 are made from equation 28-0 assuming prices will be at 1955-59 levels and that the structure of demand indicated by the equation will remain applicable. Projections are based on two estimates of S_p. The lower estimate is based on USDA estimates and agrees with projections from equation 23, Chapter 9. The higher estimate of S_p is found from an investment equation containing an accelerator coefficient (cf. equation 28, Chapter 9). Under the above assumptions, equation 28-0 projects the 1965 demand quantity to be seven or eleven percent above the 1960 predicted quantity, depending on whether the higher or lower estimate of S_p is used.

Summary of Empirical Results

In Chapter 6, we analyzed the individual demand structures for six operating inputs: fertilizer, seed, machinery

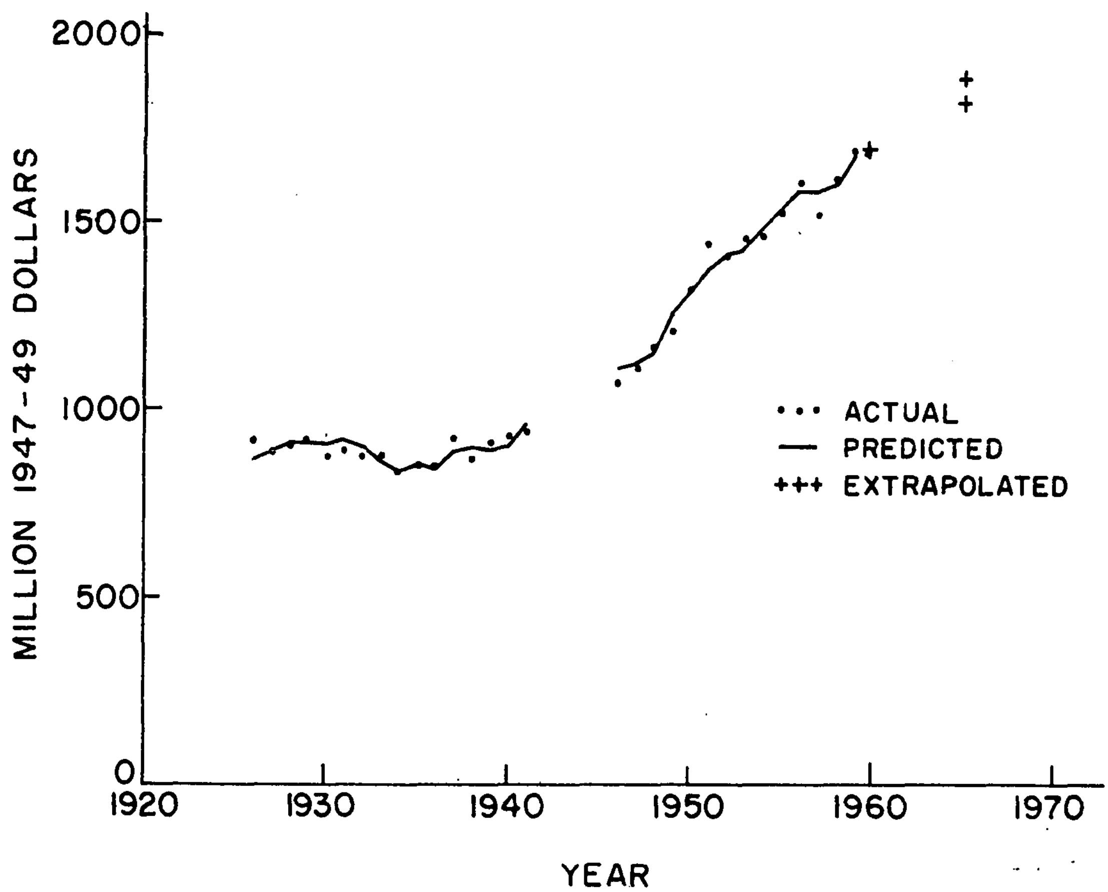

Figure 6. Trends in purchases of miscellaneous operating inputs Q_{MI} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 28-0

supplies, feed, building repairs and miscellaneous operating inputs. Demand functions were estimated by least squares with the demand quantity a function of relative prices, the asset structure, government programs, weather and slowly changing influences represented by a time variable. The equations were fitted to annual data from 1926 to 1959, excluding 1942 to 1945.

The generalized results are summarized in Table 7. Despite similar trends in prices and quantities of several of the indicated operating inputs, the estimates of price effects and projected quantities often are dissimilar. The empirical results suggest that the short run price elasticity of motor supplies, building repairs and feed approximately is unitary. Seed and miscellaneous inputs are unresponsive to short run price changes. The short run price elasticity of fertilizer purchases with respect to P_{Fr} approximately is -0.5 and ranks between the above extremes.

The equations providing for the scale of the agricultural plant S_p generally provided the most meaningful expressions of demand. The coefficients of lagged dependent variable, introduced as a predetermined variable in equations containing S_p, were insignificant. The implication is that there are no long run adjustments of operating input purchases, given the agricultural plant size. In the long run, the stock of productive assets is responsive to prices. Due to the comple-

Table 7. Summary of the analysis of demand structure for six operating inputs; short run demand elasticities, structural changes and projections of quantities are included[a]

	Input					
	Q_{Fr}	Q_{Sd}	Q_{MS}	Q_{Fd}	Q_{BR}	Q_{MI}
Approximate short run demand elasticity estimates with respect to:						
P_i (own price)	-0.5	0.0	-1.0	-1.0	-1.0	-0.1
P_R	0.5	0.0	0.3	1.0[b]	1.0	0.1
Estimated percentage change in demand quantity from 1926 to 1959 due to short run price changes[c]	30	-15	119	12	15	3
Actual percentage change in demand quantity, 1926 to 1959[c]	512	212	365	218	-19	83
Projected percentage change in demand quantity from all sources, 1960 to 1965[d]	15	12	10	12	-12	9

[a]See the respective sections for input codes, sources of data, type of analysis, qualifications of findings and other information.

[b]Elasticity with respect to P_{Lk} rather than P_R.

[c]The difference between changes due to price and actual changes is explained by lagged adjustment to price, changes in investment in durable assets, farm size, technology, education and improved management.

[d]When projections were made from two estimates of S_p, the table contains only an average of the separate estimates.

mentarity of most operating inputs with the scale of plant, the long run elasticity of operating inputs with respect to product prices P_R is large. For some operating inputs, the long run elasticity is greater than two.

Short run price changes explain only a small portion of the total change in operating input purchases from 1926 to 1959. The dominant, unexplained portion of the changes in purchases is attributed to demand shifters such as increased investment in durable assets, lagged adjustment to short run price changes, larger farms, changing technology, and to improved knowledge, education and management.

The demand equations project fertilizer purchases to be approximately 15 percent above 1960 levels by 1965. Purchases of other operating inputs are projected to increase from nine percent (Q_{MI}) to 12 percent (Q_{Sd} and Q_{Fd}). Inputs of building repairs, however, are expected to decrease from 1960 to 1965. All of the above findings must be interpreted with proper considerations of the data and other limitations discussed in the respective sections, of course.

CHAPTER 7: A FRAMEWORK FOR ANALYSIS OF FARM INVESTMENT BEHAVIOR

The changing capital structure of American agriculture may be dramatized by comparisons with the capital structure of manufacturing industries. In 1939, capital per worker in agriculture was $3,400; in manufacturing was $5,300 (31).[1] But by 1960 capital per worker in agriculture had increased to $22,100; in manufacturing to $19,900. Investment per worker is not only greater in agriculture, but it is increasing at a faster rate.

One of the prominent and unique features of the changing capital structure of agriculture has been the rapid substitution of purchased durable capital for farm produced capital. The 60 percent rise in durable assets (productive machinery and buildings) from 1926 to 1959 is less spectacular than the 200 percent rise in operating inputs. But since many durable assets such as farm machinery basically are labor and horsepower saving rather than output increasing, there is little doubt that investment was a significant feature of the 280 percent rise in labor efficiency (output per worker) from 1926 to 1959. During this period labor inputs dropped 43 percent and horse and mule inputs fell 85 percent.

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[1]Farm assets include the stock of land and service buildings, machinery and livestock. Only the productive portion is included, e.g. the farm dwelling is excluded.

The rapid capitalization of agriculture has increased real income for society in aggregate. Investment has sometimes brought mixed benefits to farmers, since the economic structure of agriculture is unsuited for retaining the gains of greater efficiency. Particularly during periods of high unemployment and depression, heavy capitalization tends to be associated with underemployment of resources and burdensome overhead costs. Furthermore, the investment structure introduces financial handicaps for beginning farmers and changing roles for credit institutions. Agricultural investment comprises approximately eight percent of total national investment, and is of interest in explaining business cycles. It is apparent that the advantages of obtaining a clearer picture of the investment process in agriculture are many.

In this and the following two chapters, we analyze investment in the following categories of durable resources: (a) motor vehicles, (b) machinery other than motor vehicles, (c) building improvements, and (d) an aggregate of all productive assets including (a), (b) and (c) plus livestock and feed inventories, and cash held for productive purposes. The specific objectives of this chapter are to: (a) illustrate graphically some of the major input substitutions taking place, (b) establish a theoretic framework for analysis of the investment process, and (c) present several statistical investment models capable of empirical verification. These models provide the basis for giving empirical content to the theoretic constructs. For convenience much of the theoretic background is based on investment in farm machinery, but the results apply in general to the other investment categories listed above.

Trends in Price and Quantity Ratios

To gain a better perspective of the major substitutions occurring in agriculture and to explore the role of prices in these substitutions, Figures 1 to 4 are presented to illustrate the direction and extent of the substitutions taking place between machinery and other major farm inputs and farm output from 1910 to 1959. Previous econometric studies and this study (anticipating the results of Chapters 8 and 9) have not adequately isolated the influence of labor and other input costs on investment. The graphic illustrations are subject to the limitations of a two dimensional analysis, but provide an insight into the price-quantity relationships not readily offered by more sophisticated econometric techniques.

The substitution effect is expected to dominate in most instances, i.e. as the price of machinery falls relative to other prices, the machinery input is expected to increase in relative importance. Machinery inputs Q_M' are measured as the services required to maintain farm machinery and motor vehicles (40 percent of auto) for productive purposes. Q_M'

includes depreciation, license fees, insurance and interest on inventory.

Figure 1 illustrates indices of the ratios: (a) Q_M' (4) to operating inputs Q_O', and (b) machinery price P_M to the price of operating inputs P_O. The price ratio has remained comparatively stable, but the general trend is upward. The ratio of quantities declined slightly from 1910 to 1950. The stable ratio of quantities may be explained by the strong elements of complementarity in the two inputs e.g. between tractors and motor fuels.

Figure 2 depicts the indices of the ratios: (a) Q_M' to total labor employment in agriculture Q_{TL}, and (b) P_M to the wage of hired labor P_{HL}. Major substitutions have occurred particularly since 1946. The substitutions cannot be explained entirely by relative prices; other influences such as technology undoubtedly have been important. From 1910 to 1930, the relative prices remained almost unchanged, yet machinery inputs increased relative to labor. Introduction of new tractors, combines, etc., and improvement of existing models performed an important role in the substitution. Although prices remained almost unchanged from 1946 to 1959, the ratio of machinery to labor inputs grew by major proportions. One explanation is that the relative decline in machinery price from 1940 to 1946 created a latent demand which could not be filled until the postwar period. Furthermore, depreciation depleted machinery stock in the war years,

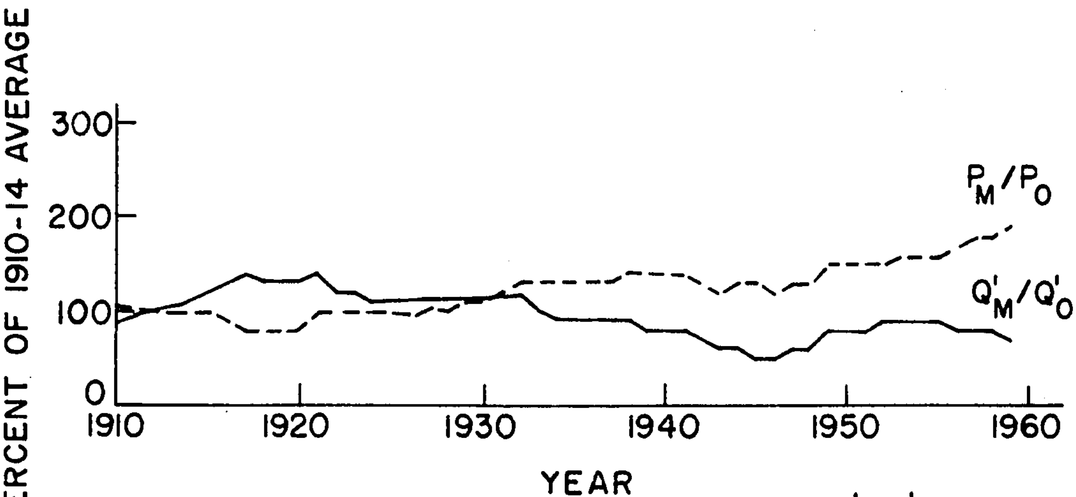

Figure 1. Indices of the ratios P_M/P_O and Q'_M/Q'_O from 1910 to 1959; 1910-14 = 100 (P_M and Q'_M are all farm machinery price and quantity; P_O and Q'_O are operating input price and quantity)

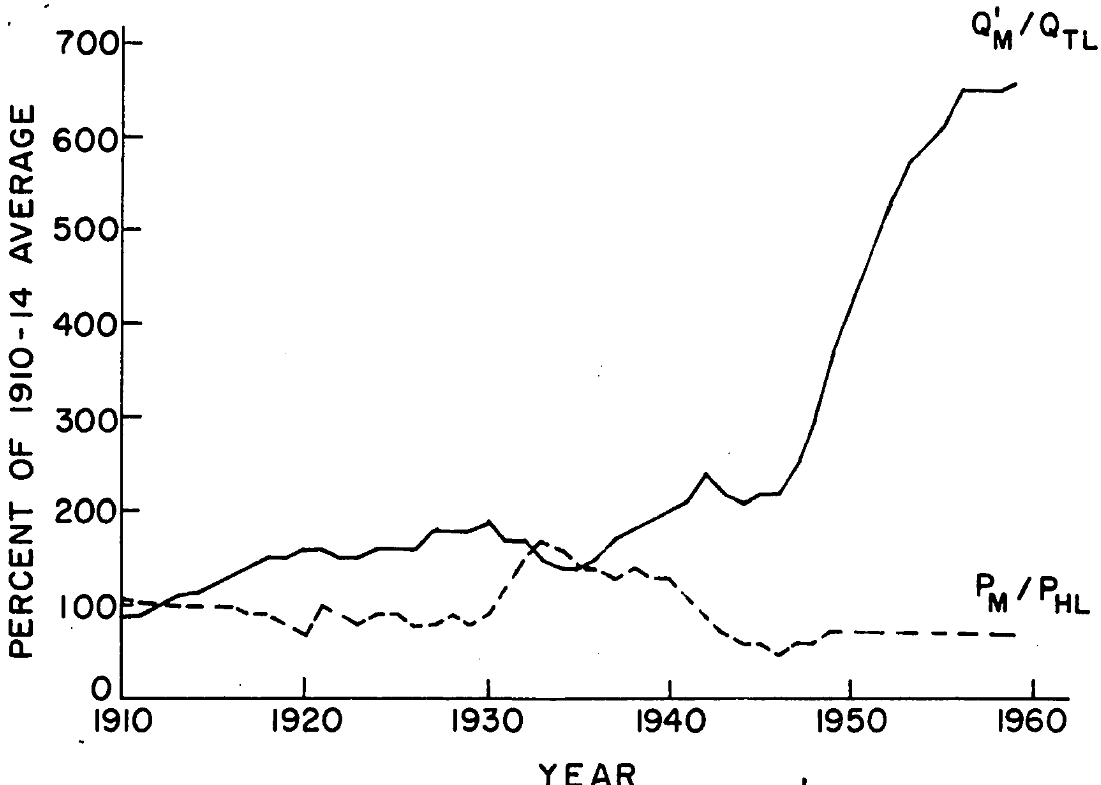

Figure 2. Indices of the ratios P_M/P_{HL} and Q'_M/Q_{TL} from 1910 to 1959; 1910-14 = 100 (P_M and Q'_M are farm machinery price and quantity; P_{HL} is the wage rate of hired labor and Q_{TL} is total farm employment)

and machinery could not be replaced until the postwar era. Undoubtedly, improvements in existing machinery, introduction of new models and other non-price influences also have encouraged substitution of machinery for labor inputs during the postwar period.

Figure 3 indicates the indices of the ratios: (a) Q_M' to real estate inputs Q_{RE}, and (b) P_M relative to land price P_{RE}. Despite the tendency for machinery prices to rise relative to land prices, the ratio Q_M'/Q_{RE} increased from 1910 to 1940. After 1940, machinery prices declined relative to land prices, and the relative importance of machinery inputs increased sharply. Since 1955, however, the input ratio has stabilized. The lack of correspondence between price and quantity ratio may arise because land price is not an important decision variable in machinery purchases. Cash expenses such as hired labor, and operating inputs, and the expected returns from sales of farm output are examples of decision variables that may be of greater importance.

In Figure 4, two graphs illustrate: (a) the ratio of P_M to prices received by farmers for crops and livestock P_R, and (b) the ratio of Q_M' to agricultural output O from 1910 to 1959. Since total inputs are nearly equal to output, the ratio Q_M'/O is an indication of the relative importance of machinery in the total input mix. The quantity ratio was quite stable until 1940. During the decade of the 1940's,

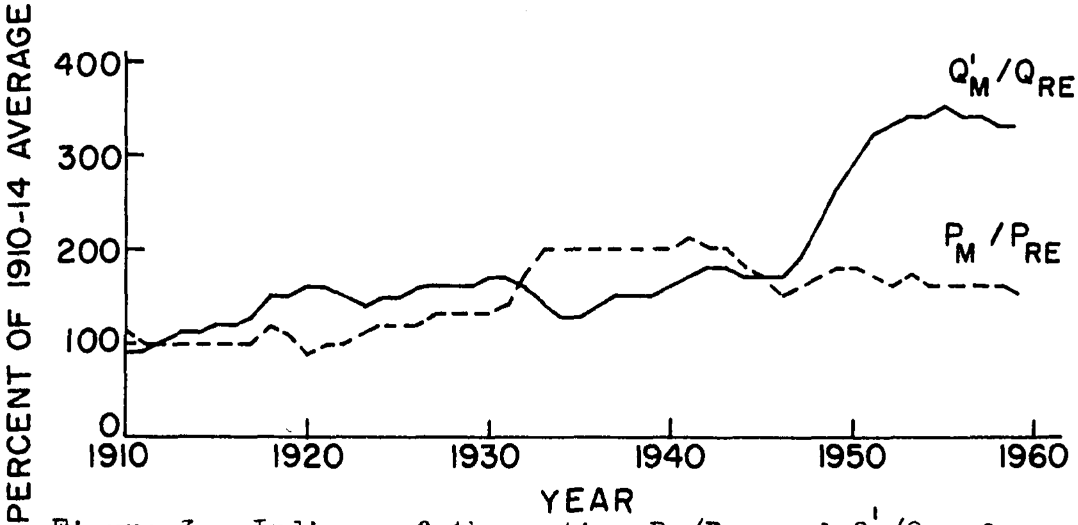

Figure 3. Indices of the ratios P_M/P_{RE} and Q'_M/Q_{RE} from 1910 to 1959; 1910-14 = 100 (P_M and Q'_M are farm machinery price and quantity; P_{RE} is the land price per acre and Q_{RE} is input of real estate)

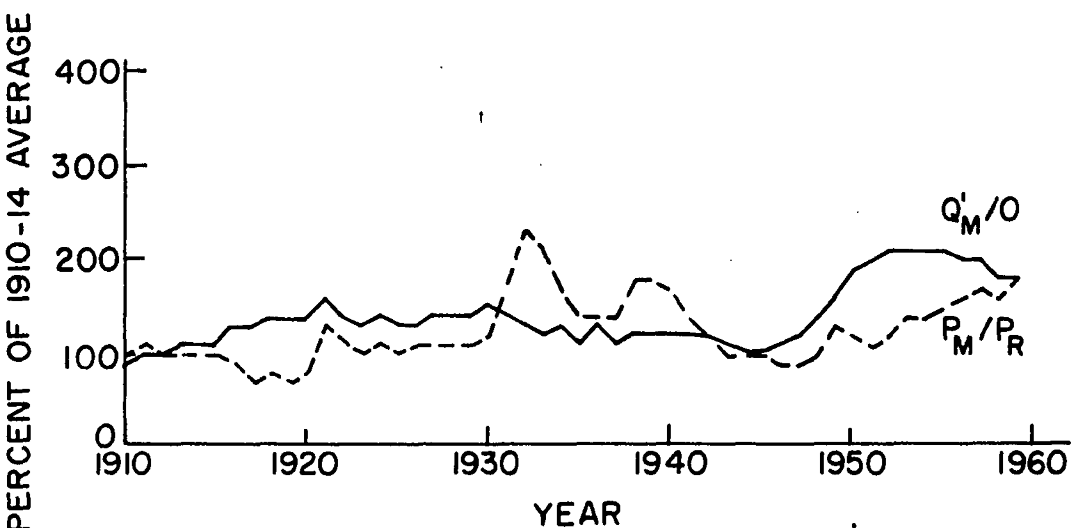

Figure 4. Indices of the ratios P_M/P_R and Q'_M/O from 1910 to 1959; 1910-14 = 100 (P_M and Q'_M are farm machinery price and quantity; P_R is prices received by farmers for crops and livestock, and O is total farm output)

inputs of machinery declined in relative importance although prices were favorable because of conditions mentioned previously. In the late 1940's as machinery became available, the input began to substitute for other inputs in the production process. In the period when the backlog of demand was being filled, the quantity ratios ran counter to what might be expected on the basis of price ratios. After 1952, Figure 4 indicates that price-quantity relationships began to display the association postulated by economic theory.

Previous Quantitative Studies of Investment

Previous econometric studies of demand for durable goods in agriculture, though few, provide useful insights into some of the forces influencing the investment process. A study by Kendrick and Jones (77) published in 1953 specified the outlay for farm plant and equipment (machinery and building improvement) as a simple function of net farm income. Using least squares and annual time series from 1910-41, they found a significant relationship between income and investment, and estimated the income elasticity of demand for plant and equipment as 1.08 (77, p. 17). They also noted that farm capital outlay was a relatively constant proportion, 20 percent, of net cash income from 1910 to 1941.

In 1959, several demand studies appeared for durable inputs in agriculture. Griliches (46) published an econometric analysis of the demand for farm machinery -- the study was published in more detail in 1960 (44). He specified two principle demand functions: (a) the stock of farm machinery as a function of the past price of machinery relative to prices received by farmers, the rate of interest and lagged stock; and (b) the annual investment in machinery as a function of current price, the rate of interest and beginning year stock. He found the short run price elasticity of the tractor stocks to be -0.25; the long run elasticity -1.50. The adjustment coefficient (defined later) was 0.17, indicating the long run is "far away". Elasticity with respect to the interest rate was approximately -1.0 in the short run; from -4.5 to -10.3 in the long run (46, p. 315). His study indicates that the interest rate elasticity is considerably higher than the price elasticity. Specification of the price of labor, the price of motor supplies, a time trend, a capital gains variable, the stock of horses and mules on farms, and alternative measures of the stock of tractors on farms did not improve the results (46, p. 314).

Also in 1959, Cromarty published studies of the demand structure for farm machinery and tractors (24, 26), and for farm trucks (27). He specified the demand quantity of farm machinery (value of manufacturers' sales of machinery deflated by the wholesale price index of machinery) as a function of: (a) machinery price, (b) the index of prices received by farmers for crops and livestock, (c) the index of prices paid by farmers for items used in production, (d) the value of farm machinery at the beginning of the year, (e) asset or equity position of farmers, (f) realized net farm income in the previous year, (g) cropland acres per farm, and (h) an index of labor costs. A least squares demand equation fitted to annual data from 1923 to 1954 explained 95 percent (adjusted R^2) of the variation about the mean of the dependent variable. Only variables (c), (e) and (h) were significant in the equation. The sign of the labor cost variable (h) was negative and does not support the hypothesis that machinery is substituted for labor as farm wages rise.

In an alternative specification, Cromarty considered the machinery market as an interdependent system. The (a) deflated value of shipments of farm machinery, (b) retail price index of farm machinery, and (c) value of machinery produced were determined interdependently in a system of three equations. The two predetermined variables that most significantly explained the three endogenous variables were (a) the wholesale price index of farm machinery, and (b) industrial wage rates. Predetermined variables such as the parity ratio, beginning year assets, a quantified measure of farm price programs, changes in manufacturers inventories, steel price and a measure of plant capacity had little influence on the endogenous variables -- using the ratio of the coefficient to the standard error as the criterion.

Specification of the Investment Function

Interesting, complex investment functions providing for interaction of investment and accelerator that explain cyclical fluctuations in investment have been formulated by Samuelson, Hicks and others (cf. 1). Refined models allowing for macro influence of aggregate demand seem inappropriate for agriculture since: (a) agricultural investment is a sufficiently small portion of total investment that the macro effects may be ignored as a reasonable approximation, and (b) it is necessary to construct less refined models compatible with statistical procedures and data limitations. The procedure in this study is to develop as simple models as possible consistent with the desired information about the parameters of the investment process.

It is rational to purchase an additional durable asset if the present value of discounted future earnings exceeds the cost of the asset. The rate of discount might be the bank rate of interest if uncertainty were absent, but in agriculture a liberal discount for risk and uncertainty and capital limitations must be made. Future earnings are determined by the sales price of the product and the flow of services from the durable stock in the production function. Because the flow of services from a durable good tends to be proportional to stock, the annual investment essentially is derived from the desire by farmers for a given level of stock. For a durable input, the flow of services from stock rather than annual purchases is the relevant input in the production function. It does not necessarily follow that the stock of assets rather than annual investment should be the dependent variable in the investment function. Although the objective may be some optimum inventory, the variable manipulated by farmers to achieve the proper level of stock is annual purchases (gross investment). In this study, the annual investment is chosen as the dependent variable rather than stock since the former is a more volatile quantity and sensitive measure of investment behavior. Furthermore, by proper structuring of the investment equations, it is possible to infer results about stock levels from knowledge of annual investment. In the following pages, a number of other variables are specified as relevant in the investment function.

Application of mathematical tools and rigorous logic of the classical economists resulted in well defined demand functions for durable goods. Under certain rigid assumptions, the volume of investment is determined by the cost of capital and the market rate of interest (95, p. 8). Because of the growing awareness of the role of investment in business cycles, considerably more attention has been focused on investment behavior in recent years. In general, the trend has been to relax the unrealistic classical assumptions and to allow assumptions more nearly approaching real world conditions. The result has been a declining importance of interest rates as the core of the investment theory, and greater emphasis on the nature of expectations and adjustments. Profit maximization is no longer the only assumed motivator for the decision process, but allowances are made for utility maximization, reflected by the desire for security (e.g. game theory minimax criterion), convenience, stability, etc.

Lagged stocks

The demand for gross annual investment is derived from two sources: (a) desire to increase stock levels, and (b) need to replenish existing stock because of depreciation. The level of past stock exerts an opposite influence on these two sources of demand. The greater the level of beginning year stock, the greater the depreciation and demand for replacement stocks. But *ceteris paribus*, greater stock levels decrease the marginal product of investment goods and reduce the demand from source (a) above. Because the declining balance depreciation method (depreciation a linear proportion of stock) is considered realistic, inclusion of beginning year stocks in the linear investment function represents source (b), the coefficient of lagged stock being the rate of depreciation. In some instances the rate of depreciation changes or the same level of stock at two points in time do not indicate comparable replacement demands because the total stock is newer at one point in time. Refinements such as these can be introduced into the demand function if necessary. The greatest challenge, however, is to select variables to represent investment source (a) -- the desire to increase or decrease stock levels. Several variables might be suggested.

Net farm income

The variable most often suggested in empirical analysis of non-farm industries as the source of investment is net income or corporate profits. Studies by Meyer and Kuh (95), Tinbergen (112), and several other studies cited by Kuh (86) show that profits are an important variable determining the actual rate of investment. Grunfeld states, however, that while profit may be a useful indicator of investment behavior, better indicators might be found (52). He finds that the market value of the firm predicts investment better than profits. The studies of investment in agriculture by Cromarty (23) and Griliches (46) indicated no significant importance of net income in explaining demand for farm durables. But the study by Kendrick and Jones (77) does indicate that net farm income is useful in explaining aggregate investment behavior.

The argument for inclusion of net income in the investment function is strong. Net farm income (gross receipts less production expenses) Y_F is an important expectation variable for two reasons. First, it is an indication of the returns from the durable resource. After subtracting production costs from gross returns, the remainder may be interpreted as the return to family labor and durable resources. Farmers subjectively impute little return to their own labor, hence, a tendency exists to attribute the return to fixed capital. Theoretically, the decision to purchase a durable resource is made if the present value of discounted future earnings from the asset is greater than the purchase price. Because expected future earnings from durable resources tend to be based on past earnings, lagged values of Y_F in the demand function may be important.

The second reason for including Y_F in the investment function is because the variable is an important indication of the future financial capabilities and ability to pay for the asset. Investment in a durable asset such as machinery entails considerable financial encumbrance in many instances. Although the current price of machinery is low relative to prices received, a farmer may hesitate to invest unless he feels assured of future earning potential -- and the degree of assurance often depends on past income. Financial institutions employ similar decision variables to determine the feasibility of a loan. External credit availability is often determined to a greater extent by the ability to repay the loan than by the profitability of the specific investment. Though the marginal efficiency of a particular investment is high relative to the interest rate, credit sources may be reluctant to make the loan if the marginal efficiency is highly variable or if the return from the capital is likely to be consumed by the household sector. Since the household competes with the credit source for added returns, if net income is low but the marginal efficiency of investment is high, lenders may be reluctant to provide funds. The conclusion is that net income reflects both the internal and external financing capabilities of the farm firm. The Farmers Home Administration is the only "major" organization designed to provide loans to farmers who "can't show they don't need it". The organization provides only two to three percent of the mortage loans in a given year, however (54, p. 86).

Decisions to invest in farm machinery and other durables are often uneconomic. Appendix A and other studies (56, pp. 554-639) indicate that many U.S. farmers are "machinery poor". Farmers occasionally purchase additional machinery because of greater convenience or prestige despite the absence of added returns. These purchases might be regarded as consumption rather than production items and emphasize the intimate interaction between the firm and household in the investment processes. The marginal efficiency of capital and the interest rate may have little influence on such purchases. Net income is not only the cheapest source of funds but in many instances may be the only source of funds for such purchases. Ability to pay for the uneconomic asset depends heavily on net income, and past values of Y_F again are likely to be an important decision variable -- both for the farmer and the external credit source.

Income is determined by prices, weather, technology and other influences that could be specified individually in the demand function. Ideally, it would be desirable to include each component of Y_F separately in the demand function to determine the relative impact of each on the demand quantity. Because the least squares model tends to degenerate with the large numbers of variables that necessarily would be required, it is desirable to sacrifice some information about the individual components of Y_F to gain a more accurate estimate of the <u>total</u> impact of Y_F on the demand quantity. Furthermore, the hypothesis that farmers focus attention on a single decision variable such as net income rather than attempt to digest the implications of the myriad components of Y_F appears reasonable.

Use of gross receipts in the investment function essentially reflects only the product price; net income reflects input prices as well. The structure of agriculture has changed, permitting greater sales but requiring more input purchases. That is, output is greater because agricultural resources formerly produced on farms are now purchased. Use of gross receipts in the investment function would contain the bias of this structural change while net income is corrected for some of this structural change.

Equity

Assets other than investment stock of the particular demand asset are important in the investment function. The demand for a durable asset depends on the form and abundance of farm assets. Assets held in a liquid form such as cash reserves and government bonds provide most flexibility of input purchases. Many assets are technically related -- a large stock of big tractors may stimulate demand for four or six row planting, cultivating and harvesting machinery.

The ratio of proprietors' equity to total liabilities reflects several influences on demand in a dynamic agriculture. First, it is a measure of the vulnerability of the farm firm to uncertain outcomes. According to Kalecki's (76) principle of increasing risk, the unfavorable impact of an uncertain event is an increasing function of the firm's equity position. That is, a given loss causes little concern if equity is high, but if equity is low the same loss may increase liabilities above equity, creating an insolvent firm. The equity ratio is a measure of this influence both psychologically for the farmer and actually for outside credit sources.

The equity ratio also indicates the capital gains of ownership through inflation. Since liabilities in the short run do not reflect inflationary influences to the extent they are reflected in real assets such as land, the equity ratio tends to increase in an inflationary boom. Because capital gains due to inflation can be a source of funds for investment, it seems logical to include the influence in the investment function.

Finally, and perhaps most important, the equity ratio may be regarded as the culmination of the income generating process. Periods of high income provide an opportunity for farmers to pay debts and build equity. In the long run a large portion of these gains is likely to find its way into additional investment. Hence, the equity ratio is a kind of proxy variable for past income. If income has been favorable for several years, it tends to be reflected in the equity ratio because of the lagged adjustment of consumption and durable purchases to higher income.

Monetary variables

The interest rate is a fundamental concept in marginal theories of investment. Yet, Meyer and Kuh (94, p. 8) state that "empirical findings . . . indicate that the interest rate is not important whether statistical inference, interviews, or questionnaires have been the method of investigation". Logic and introspection suggest that the interest rate probably is overshadowed by other variables as a determiner of investment. Because of fluctuating weather and other stochastic elements, the marginal efficiency of capital varies widely and is of far greater concern to farmers than the interest rate. Studies by Kendrick and Jones (77, p. 18) and by Cromarty (23, 26) give the interest rate a very secondary role in farm investment decisions. The study by Griliches (44, 46) however, indicates that tractor purchases are highly sensitive to changes in the interest rate. More research is needed to determine if the latter result was because of failure to specify other <u>trend</u> variables such as farm size, asset structure and technological changes in the demand function, or if, in fact, the interest rate is highly important.

The capital market is not perfect, and institutional restraints of lending agencies may be of greater significance than the interest rate in restraining loans to farmers. Tostlebe's study (114, p. 21) indicates that farmers have supplied the major share of the funds financing capital acquisitions. But there is evidence that the externally financed portion of capital acquisitions is increasing (54, p. 88; 64, p. 249). Moreover, it may be argued that external capital sources have a significant marginal impact on investment. Because the external capital agencies such as the Farmers Home Administration lending funds which might be "marginally" important are few, and because studies indicate that internal farm management, not credit restrictions is the greatest investment restriction (58, p. 37), the institutional restraints are not explicitly included in this study. Institutional restraints on credit are defined as factors other than the interest rate affecting the availability of funds from credit institutions. To a large extent, it is believed the influences affecting institutional credit restraints are reflected implicitly in the investment function through the income and equity variables discussed earlier.

Price variables

As indicated previously, some price variables are implicitly included in net farm income. Prominent price variables which might be singled out for their hypothesized unique and prominent influence on investment are the own-price of the durable and the farm wage rate. The price of the durable is likely to be particularly important in the short run. That is, even if equity, earning power and other financial variables are favorable, the final decision to purchase may be based on the input price. Once the input is purchased, the price is of historic interest only. Farmers need not be greatly concerned with expectations and future trends since ability to pay for the input does not depend on what happens to the price, once the durable is purchased. But the ability to pay for the input does depend on wage rates, operating input prices and on farm output prices. These latter prices are more likely candidates for expectation variables. The farm wage rate might be singled out as a separate variable in the investment process because of the large substitution of capital for labor indicated in Figure 2. Past efforts to measure the influence of wage rates on farm investment demand largely have been unrewarding, however (23, 46, 77).

The accelerator

The argument for the accelerator is based on an assumed fixed ratio of output to durable capital. In the short run, a decision by farmers to increase output could be realized by applying more operating inputs. But given time to increase durable capital, the former ratio of durable capital to output would be restored according to the argument. Inclusion of an output variable in the investment function would accommodate this accelerator effect.

The need for the accelerator depends on the investment structure being investigated. For farm machinery and buildings, the range of substitution with labor and operating inputs is large because of the technical characteristics of the inputs. Also, because farmers tend to be overinvested in machinery in many instances, a considerable increase in output could occur without increasing machinery inventories. There appears to be no strong basis for inclusion of the accelerator in the case of farm machinery because the ratio of stock to output is quite flexible.

The basis for the accelerator is stronger for investment in livestock and feed inventories. The nature of these resources suggests there are few substitutes. A certain number of breeding stock and feed inventories are needed for a sustained output, and this ratio of inventories to output is likely to be quite rigid in the long run. The ratio, of course, has secularly declined due to growing efficiency. In the short run, farmers can increase output by selling breeding stock, but if output is to be sustained at the old level or at higher levels, the inventory level must be raised. Thus, the argument for the accelerator is strong in an investment analysis including livestock and feed inventories. The assumption is that productive livestock and feed inventories, unlike machinery, do not have properties of a consumption good and, therefore, are not characterized by opportunities for substitution caused by overcapacity.

The foregoing logic appears to be anachronistic, since it is also reasonable to say that greater investment causes greater output. Undoubtedly, some elements of simultaneity are present and, in the absence of more sophisticated techniques, least squares bias may be present. We attempt to reduce the bias by using lagged rather than current output as an explanatory variable in least squares investment functions in this study.

A considerable academic controversy exists over the relevance of first differences or original values to represent the accelerator influence. In a 1951 article, Kaldor (75) summarizes several positions taken by different economists. Rather than become involved in the polemic, we adopt a pragmatic approach and use the form giving most realistic results. In several preliminary regressions, output and income variables were included both in first differences and original values. Without exception, the equations linear in untransformed, original data were more realistic and acceptable from a statistical and economic standpoint.

Other variables

Of the many additional variables that might be specified in the investment function, farm size, government programs and technological and other changes reflected in a time trend variable are good candidates. A farmer acquiring an additional farm may work the added acres with the same capital equipment but with longer hours of labor and more operating inputs such as fertilizer, fuel, oil and repairs. But given time, he is likely to increase his capital stock of machinery, livestock and feed. Whether the final, total investment in assets will be greater than the combined assets of the new owner before the sale and the former owner of the acquired farm is difficult to judge. Many would agree that the reduction in farm numbers has increased demand for machinery.

The influence of government programs is twofold: acreage restrictions and marketing quotas reduce demand for machinery but price supports improve the financial position of the farmer, encouraging investment. The net influence is not clear.

A major portion of the basic farm machines including the row-crop, rubber tired tractor were in existence in the 1920's. But continual refinements of the basic machinery to provide greater versatility, convenience, efficiency and other advantages suggests that technological changes have played an important role in the demand for durable assets. Furthermore, knowledge of the advantages of the new and improved investment items came as a gradual process to farmers. These and other gradual influences are best represented by a time trend in the investment equations.

Causal structure

The rationale for a single equation investment function in agriculture is based on several considerations. Using machinery as an example, some evidence is available indicating that current prices are somewhat unresponsive to purchases (cf. 23, p. 34). If the supply of farm machinery is highly elastic as implied, the supply function need not be estimated simultaneously with the demand function. However, specification of income and output variables in the demand function as discussed earlier, may violate the monocausal structure. That is, income and output may be a function of investment and vice versa. Because studies indicate the marginal product of machinery is low, and because services of durables are spread over the long run, additional investment is expected to influence output and gross income very little in the short run. It follows that least squares bias may be small and the monocausal structure implied by the single equation is a reasonable approximation. Nevertheless, there appears to be sufficient quarrel with the argument to warrant inclusion of a machinery demand function estimated by limited information. The model is discussed in detail in Chapter 2. The models presented in this chapter are based on single equations only.

It is obvious from the foregoing discussion that a very large number of variables could be specified in the investment function. The number must be reduced, however, to a relatively few important influences consistent with the estimational "capacity" of existing statistical models and available data. More responsibility is placed on the researcher's judgment than is commonly realized since the reduction cannot be based on objective statistical tests. That is, several quite different specifications may give equally acceptable statistical results. It is well to keep these limitations in mind and remember that the final investment model is a product of the researcher's judgment as well as of statistical inference. In this study, the investment function for machinery, for example, is specified as

(1) $Q_M = f\ (P_M/P_R,\ P_M/P_{HL},\ Y_F,\ E,\ S_p,\ S_M,\ A,\ r_S,\ G,\ T)$.

The demand quantity (annual purchases or gross investment) is a function of the price of machinery P_M relative to prices received P_R and to wages of hired farm labor P_{HL}, net farm income Y_F, the equity ratio E, stocks of productive assets S_P, stocks of machinery S_M, farm size A, short term interest rate r_S, government programs G and time T. The logic of these variables is apparent from the foregoing discussion. Time subscripts are not included in equation 1 because the nature of the time lags needs further discussion.

Expectation and Adjustment Models of Investment

The use of distributed lag models to express investment behavior is justifiable on several grounds. First, expectations are important in determining the profitability and ability to pay for a durable asset. The principal expectation variable discussed earlier is net income -- primarily the output prices and weather components since they are least predictable. A somewhat different form of distributed lag model may arise if farmers are subjectively certain of the favorable price and financial conditions. A lagged adjustment to an equilibrium or desired quantity may result if farmers adopt a wait-and-see attitude (how will the neighbor like the machine?), postpone purchase because of inertia of past decisions, feel repair facilities for the machine are inadequate, etc.

One of the prominent features of modern econometric research is the emphasis on simple, structural equations providing information about long and short run coefficients, adjustments, expectations and other information (85, 98, 99). Various types of statistical distributed lag models may be devised to approximate the actual farm investment function. Each has unique advantages, depending on the nature of the "true" function. But none of the models possesses all the properties desired in a general model. It is useful to consider several of these models and base the final choice on the basis of empirical results as well as on a priori considerations.

Model A

The most general model of demand is formed by allowing the parameter estimates of lagged variables to be unrestricted. It is useful to assume that the true model is linear in the parameters, but the estimated parameters of the lagged variables need not be forced to decline at a linear or geometric rate. Model A, used in this study, is of that form. Expected income Y_F^* is a function of past income, i.e.

$$(2) \qquad Y_{Ft}^* = a + b_1 Y_{Ft-1} + b_2 Y_{Ft-2} + \cdots + b_n Y_{Ft-n} \ .$$

To form model A, the demand quantity or stock is considered a function of expected income, the ratio of machinery price P_M to prices received by farmers P_R, time T and error u.

$$(3) \qquad Q_{Mt} = a = b\ Y_{Ft}^* + c\ (P_M/P_R)_t + d\ T + u_t \ .$$

The least squares estimate of model A is formed by substituting the right side of equation 2 for Y_F^* in the demand equation 3. The advantage of model A is that no assumption is made of the magnitudes of the coefficients of lagged income, but practical statistical considerations such as loss of degrees of freedom and multicollinearity limit the number of coefficients which may be estimated with reliability. One might continue to add lagged variables until the coefficients of the additional variables are non-significant, or the adjusted R^2 falls, and/or the coefficients become unstable. Unfortunately, it is impossible to determine if an additional variable fails to improve the equation because of statistical problems or because the true farm decision function does not include the variable.

If model A is the appropriate demand function, an autocorrelated error structure arises from failure to accommodate the distributed lag in the estimation process. Assuming model A is correct and the model is estimated by least squares with income lagged only one year, the effect of Y_F on purchases for the remaining n-2 years becomes part of the unexplained residual. The error would not be distributed randomly, but likely would display positive autocorrelation.

Model B

A second distributed lag model of machinery demand is formed by selecting an explanatory variable which is the realization of the income generating process. The variable chosen is E, the ratio of farm proprietor's equity (owned assets) to liabilities. We assume that equity on January 1 of the current year is a function of farm income in the past n years.

(4) $$E_t = a + b_1 Y_{Ft-1} + b_2 Y_{Ft-2} + \cdots + b_n Y_{Ft-n} .$$

Thus E may be used as a proxy variable for Y_F^*. The demand model B is formed by substituting E_t for the expected income in equation 3, i.e.

(5) $$Q_{Mt} = a + b E_t + c (P_M/P_R)_t + d T + u_t .$$

If E_t is a realistic indication of expected income, models A and B are equivalent. The advantage of model B is that only the single variable E_t needs to be included in the least squares regression to represent the lagged income and other effects discussed earlier. But information about the b_i

values in equation 2 is lost, although an estimate of these can be found from a least squares estimate of equation 4. The equity ratio is a useful indicator to both the farmer and credit institutions of the current financial position of the firm and is a measure of ability to finance an additional durable asset. The variable is also useful in indicating the vulnerability of the firm to an unfavorable financial event. Finally, it reflects to some extent the capital gains and improved financial capabilities arising from inflation. If net income is quickly spent, E may not be a realistic indication of past net income, however.

Model C

If the number of lagged income variables that must be included in model A is large, and if a useful proxy variable such as E is not available, the expected income may be represented by making assumptions about the distribution of the b_i's in equation 2. One hypothesis is that expectations are most heavily influenced by recent variables, and that the influence of past variables decline at a linear rate. Using this approach, and assuming current income expectations are determined by income of the past n years, expected income is

$$(6)\quad Y^{*}_{Ft} = a + b\left[\frac{n\,Y_{Ft-1} + (n-1)\,Y_{Ft-2} + \cdots + Y_{Ft-n}}{\sum_{i=0}^{n}(n-i)}\right]$$

and if n = 3, we may write equation 6 as

$$Y^{*}_{Ft} = a + b \left[\frac{3Y_{Ft-1} + 2Y_{Ft-2} + Y_{Ft-3}}{6} \right] .$$

Model C is formed by substituting the variable in brackets for expected income in equation 3. One might wish to experiment with several values of n and choose the appropriate value on the basis of the R^2 or other criteria. The distribution need not, of course, be restricted to the linear form illustrated in equation 6. More imaginative forms such as a distribution forcing the b_i's to decline at a geometric rate might be employed. A distribution declining by equal decrements as in equation 6 is intuitively appealing. Crudities of the data may prohibit statistical tests for isolation of a more realistic form.

Model D

Ladd and Tedford (89) propose a linear long run equilibrium model called the generalized Working method which we slightly modified to provide a useful investment function. The expected income may be expressed as

$$(7) \quad Y^{*}_{F} = a + b_1 Y_{Ft-1} + (b_1 - k)Y_{Ft-2} + \cdots + \left[b_1 - (n-1)k\right] Y_{Ft-n}$$

where k is the annual decline of the income coefficients. When $b_1 - (n-1)\,k=0$, no additional terms need be added. Simplifying terms, equation 7 becomes

$$(8) \quad Y^{*}_{F} = a + b_1 Y_{AFt-1} + k\, Y_{WFt-1}$$

where Y_{AF} and Y_{WF} respectively are simple and weighted averages of past income (89, p. 227). Substituting the right side of equation 8 for expected income in equation 3, model D is formed.

The chief disadvantage of model D is that the year t-n when income no longer influences current expectations is not determined explicitly by the model. It may be useful to estimate model D with average and weighted income variables with increasingly greater lags. The magnitude of the adjusted R^2 might be used as the criterion for finally selecting the appropriate value of n.

The advantage of model D is that only two variables need be used to represent expected income, hence, it is suitable for least squares estimation. If b_1 and k are positive and significant, the coefficients of lagged income decrease by equal decrements k, and models C and D essentially are equivalent. Model D allows more flexibility in determining the nature of the income lag, however. If k is zero and b_1 is greater than zero, the model implies that income expectations are influenced equally by n past incomes and not at all by income beyond n. That is, the income expectation can be represented by a simple average of n past incomes.

Model E

If the expected change in income is proportional to the error made in estimating income last year (the difference between actual income and expected income last year), another type of expectation model is generated (99). The model, expressed mathematically is

$$(9) \qquad Y^*_{Ft} - Y^*_{Ft-1} = e\,(Y_{Ft-1} - Y^*_{Ft-1})$$

where e is the expectation coefficient. If we solve for current expected income Y^*_{Ft}, then for Y^*_{Ft-1} in the basic demand equation 3 and substitute these values into the expectation equation 9, the following model E is formed

$$(10) \quad Q_{Mt} = a' + beY_{t-1} + c(P_M/P_R)_t - c(1-e)\,(P_M/P_R)_{t-1} + deT + (1-e)\,Q_{Mt-1} + u_t - (1-e)\,u_{t-1}\;.$$

It may be noted that for autocorrelation to be absent in equation 10, the error structure in equation 3 must be quite complicated. Two estimates of 1-e are available -- from the lagged quantity and lagged price. Model E is sometimes approximated in least squares analysis by omitting the lagged price variable. The value of e is assumed to lie between zero and one, and implies that the influence of successively distant prices declines at a geometric rate but never reaches zero.

Income may not be the only expectation variable in the demand function. The extent of modification of model E to accommodate other expectation variables depends on the nature of the respective expectation coefficients. If the expectation coefficient is the same magnitude for all variables, the model becomes comparable to the following adjustment model F.

This situation is very unlikely, however.

Model F

The previous demand models basically have been expectation models, that is, farmers are assumed to base purchases on expected net income. Model F is an adjustment model. The basic assumption is that farmers are subjectively certain of the current explanatory variables in the demand equation 1, but adjust purchases slowly to desired levels because of psychological, institutional, or other reasons. In many instances, it is reasonable to assume that the greatest adjustment would be made toward the desired or equilibrium level of purchases in the early years. As the equilibrium level of purchases is approached for the farm firm, the annual adjustments become very small. A model of demand proposed by Nerlove (98) is based essentially on these conditions. The actual adjustment in purchases in year t is a constant proportion g of the difference between the desired or equilibrium level of purchases in the current year Q^{*}_{Mt} and the actual purchases during the past year.

(11) $$Q_{Mt} - Q_{Mt-1} = g\ (Q^{*}_{Mt} - Q_{Mt-1})$$

or

$$Q_{Mt} = g\ Q^{*}_{Mt} + (1-g)\ Q_{Mt-1}\ .$$

The equilibrium quantity is a function of income, prices and time, or

$$(12) \qquad Q^*_{Mt} = a + b\, Y_{t-1} + c\, (P_M/P_R)_t + d\, T + u_t \;.$$

The term u_t is the residual in year t. Substituting the right side of equation 12 for Q^*_{Mt} in equation 11, model F is

$$(13) \quad Q_{Mt} = ag + bg\, Y_{Ft-1} + cg\, (P_M/P_R)_t + dg\, T + (1-g)Q_{Mt-1} + g\, u_t \;.$$

Coefficients in model F may be estimated by least squares. The single estimated coefficient of Q_{Mt-1} is 1-g, from which the adjustment coefficient g may be found. The coefficients of the price and income variables are short run coefficients. The long run coefficients b and c in equation 12 are found by dividing the coefficients in equation 13 by g. Variables included in model F are similar to those in model E, but the error structure in the latter is somewhat less complicated. The single equation least squares estimate of equation 13 is a more satisfactory estimational procedure if the adjustment model rather than the expectation model is appropriate. It is possible to combine expectation and adjustment models E and F into a single equation, but the necessary modifications tend to reduce the reliability of the coefficients estimated by least squares from time series (98, pp. 59, 60). If expectation and adjustments are both essential in the investment function, any one of several expressions from equations 2, 4, 6 or 8 might be substituted for Y_{Ft-1} in model F.

If a desired level of annual investment rather than stock is the goal of investment behavior, equation 13 is appropriate in the given form. But if a desired level of stock is the goal of investment behavior, then machinery stock S_M might be substituted for Q_M in the model F, or the following adjustment models might be used.

Model G

Conceptually, the principal basis for input purchases in agriculture is a subjective farm production function. Machinery inputs are an important resource in the production function, and the equilibrium or desired level of machinery input may be more nearly identified as the total stock of machinery than as annual gross investment. That is, investment in machinery during the current year may be a function of the desired level of machinery inventory since machine services are distributed over several years -- not just the year of purchase. Griliches (46, p. 314) proposes an adjustment model based essentially on this argument. The actual adjustment in machinery inventories during year t is some proportion g of the desired or equilibrium change in inventories. The adjustment to the desired machinery stock is made gradually. Mathematically, the adjustment model is

$$S_{Mt+1} - S_{Mt} = g\,(S^{*}_{Mt+1} - S_{Mt}) \qquad (14)$$

where S_{Mt+1} and S_{Mt} are machinery stocks on January 1 of year t+1 and t respectively. S^{*}_{Mt+1} is the desired or long run equilibrium stock of machinery on January 1 of year t+1.

Depreciation is assumed to be a constant proportion h of beginning year stocks. Equation 15 is an identity, indicating

$$(15) \qquad S_{Mt+1} = Q_{Mt} + (1-h)\ S_{Mt}$$

that stocks at the end of the year equal investment plus undepreciated carryover from last year. Rearranging terms, we may write equation 15 as

$$(16) \qquad Q_{Mt} = (S_{Mt+1} - S_{Mt}) + h\ S_{Mt}\ .$$

Assuming the desired level of stocks S^{*}_{Mt+1} is

$$(17) \qquad S^{*}_{Mt+1} = a + b\ Y_{Ft-1} + c\ (P_M/P_R)_t + d\ T + u_t$$

and substituting the right side of equation 14 for the term in parenthesis in equation 16, an investment model G is formed.

$$(18) \quad Q_{Mt} = a\ g + bg\ Y_{Ft-1} + cg\ (P_M/P_R)_t + dg\ T$$
$$+ (h-g)\ S_{Mt} + g\ u_t\ .$$

The long run coefficients b, c and d cannot be determined directly from model G because the values of h and g are not known. Although the values of g in equations 13 and 18 are not strictly comparable, the estimate from equation 13 (with S_M rather than Q_M the dependent variable) might be used to determine the long run coefficients in equation 17. Also, a previous estimate of the rate of depreciation h is sometimes available. If so, g can be found from the least squares coefficient of beginning year stocks h-g in equation 18.

Model G has several advantages. It explicitly recognizes machinery stock as an important variable in the investment process. The dependent variable, however, is annual investment Q_{Mt}, a more volatile and sensitive quantity. We are "explaining" considerably more if the annual investment, rather than total stock is selected as the dependent variable. Furthermore, the error structure is not particularly complicated. A disadvantage of the model is the failure to identify separate values of h and g.

Model H

It is possible to formulate an investment function using the assumptions underlying model G, but which provides estimates of g and h (98, pp. 86-93). A slight modification is made in equation 17, though it is not necessary in the formulation. Since current income may influence investment, equation 17 is modified to form equation 19.

$$S^{*}_{Mt+1} = a + b\ Y_{Ft} + c\ (P_M/P_R)_t + d\ T + u_t \tag{19}$$

Using the assumptions embodied in equations 14, 15 and 19, the following investment model H is derived

$$\begin{aligned} Q_{Mt} = A + B\ Y_{Ft} + C\ Y_{Ft-1} + D\ (P_M/P_R)_t \\ + E\ (P_M/P_R)_{t-1} + F\ T + (1-g)\ Q_{Mt-1} + V_t \end{aligned} \tag{20}$$

where $B = bg$, $C = -bg\ (1-h)$, $D = cg$, $E = -cg\ (1-h)$ and $F = dgh$. The residual V_t is $g\ u_t - g\ (1-h)\ u_{t-1}$, implying that equation 19 must follow a very complicated autoregressive pattern indeed for V_t to be distributed randomly. Assuming equation 20 is estimated by least squares from data transformed into logarithms, the following price elasticities of demand may be computed: for the short run (first year) D, for the intermediate run (two year) D + E, and for the long run D/g = c. Similar estimates can be made of the elasticity with respect to Y_F. The value of the adjustment coefficient g can be readily estimated from the coefficient of lagged Q_M. Model H is overidentified and provides two estimates of the depreciation rate: h = (C + B)/B and h = (E + D)/D. Nerlove suggests that the coefficients of the variable measured most accurately be used to estimate g. Given the value of h and g, the value of d may also be computed.

Model H is very interesting and potentially is useful because of the extended information provided by the coefficients. The chief disadvantage of the model is the frequent occurrence of lagged variables which tend to be highly correlated with current values in economic time series. Also the error structure is somewhat foreboding. Model H may be revised to conform with the investment specification of equation 17 rather than of equation 19. Merely lag Y_F one year in each of the income variables in equation 20.

Model I

The investment model G may be modified slightly to allow determination of the adjustment coefficient g. Defining

ΔS_{Mt} as $S_{Mt+1} - S_{Mt}$, equation 14 may be written as

(14) $$\Delta S_{Mt} = g\ S^{*}_{Mt+1} - g\ S_{Mt}\ .$$

By substituting the expression for desired stocks from equation 17 into equation 14, model I is formed.

(21) $$\Delta S_{Mt} = a\ g + b\ gY_{Ft-1} + c\ g(P_M/P_R)_t + d\ gT - g\ S_{Mt} + g\ u_t$$

Model I, essentially a Koyck model (85), is model G with an adjustment of the dependent variable for depreciation. This is obvious if we rewrite equation 15 as

(15) $$\Delta S_{Mt} = Q_{Mt} - hS_{Mt}$$

where net investment is equal to gross investment less depreciation. The advantage of model H is that it can be easily estimated, all coefficients are identifiable, and the error structure is relatively uncomplicated. Model I is advantageous when estimates of investment stock S_M are available and annual investment Q_M are unavailable. The dependent variable in model I is computed by taking first differences of S_M. After estimating the coefficients in model H by least squares, the short run and long run coefficients may be computed. It is possible, of course, to predict ending year stocks S_M from the predicted change in stocks $\Delta S'_{Mt}$, i.e.

(22) $$S'_{Mt+1} = \Delta S'_{Mt} + S_{Mt}\ .$$

If the rate of depreciation h is known from other sources, gross annual investment Q'_{Mt} may be predicted as

$$(23) \qquad Q'_{Mt} = \Delta S'_{Mt} - hS_{Mt}$$

and may be a useful approximation if h tends to be relatively constant.

An approximate description of the investment process depicted by models G and I aids in evaluating the coefficients of the models. Assume that product prices P_R increase one percent and that Y_F consequently increases two percent. According to the models, the first short run effect is to reduce the real price of machinery P_M/P_R, thereby encouraging some investment. Since expected income is based on past income variables, the farmer waits a year or more until he feels the income rise is "permanent" before he raises Q_M to the desired amount. In the intermediate run, after he has become subjectively certain of a favorable future income, he raises annual investment Q_M to the level necessary to reach the desired level of stock at the rate specified by the adjustment coefficient g. The complete adjustment of annual investment is made long before the desired level of stock is reached in most instances. When the maximum response or long run elasticity of annual investment to P_R is achieved, the response of stock to P_R is only partially complete and is called the "intermediate run" elasticity. Three phases of stock elasticity with respect to P_R are apparent: (a) the short run response with respect to $-P_M/P_R$, (b) the intermediate response with respect to (a) plus the P_R component of expected net income, and finally (c) the long run response after the adjustment of the desired level of stock is achieved. The desired level of stock is reached when the inventories no longer grow, i.e. when $Q_{Mt} = hS_{Mt}$. Depreciation has reached a sufficient level to consume annual gross investment.

Model J

Under different assumptions structural models such as I may be identically specified but with alternative interpretations of the coefficients. Assume that farmers are unconcerned about stock levels but only derive satisfaction from the purchase of new machinery. Further assume that they adjust immediately to this satisfactory level of purchases when they become subjectively certain on the basis of past year income that earnings will be favorable for purchasing the input. The demand equation is correctly specified as

(24) $$Q_{Mt} = a + bY_{Ft-1} + c\,(P_M/P_R)_t + d\,T + u_t\ .$$

Suppose that the right side of identity equation 15 is substituted for Q_{Mt}

(15) $$Q_{Mt} = \Delta S_{Mt} + hS_{Mt}$$

in equation 24. The resulting equation, after rearranging terms is

(25) $$\Delta S_{Mt} = a + bY_{Ft-1} + c\,(P_M/P_R)_t + d\,T - hS_{Mt} + u_t\ .$$

The phenotypes (variables included in the least squares equations) of models I and J are exactly alike. But the genotypes (true structure) of the two models are quite different. Without a priori knowledge of the investment structure, it is difficult to interpret the coefficients correctly. The model dramatizes the need for caution in interpreting the results of structured equations. Interpretation of the coefficient of lagged stock as the depreciation rate h (model J) when it actually is the adjustment rate g (model I) would be disconcerting indeed. Surprisingly, this does not necessarily lead to ambiguity in interpreting the short and long run price and income elasticities. The short run coefficient of stock with respect to $(P_M/P_R)_t$ in model I is the least squares coefficient of the price variable in equation 21. The long run coefficient is the short run coefficient divided by the adjustment rate g.

For model J, the short run coefficient of stock with respect to $(P_M/P_R)_t$ again is the least squares coefficient of the price variable in equation 25. Determination of the long run coefficient is more subtle, however. In the long run, the equilibrium level of stock S^*_{Mt+1} is reached when

(26) $$S^*_{Mt+1} = S_{Mt}$$

that is, when net additions to stock become zero, or

(27) $$\Delta S_{Mt} = 0 \ .$$

On the basis of equation 27, the right side of equation 25 is equated to zero, and the long run equilibrium level of stock occurs when

$$(28) \qquad a + b\, Y_{Ft-1} + c\, (P_M/P_R)_t + d\, T = h\, S_{Mt} .$$

Substituting the equilibrium stock relationship from equation 26, and dividing through by h, the expression for equilibrium stock is

$$(29) \qquad S^{*}_{Mt+1} = \frac{a}{h} + \frac{b}{h}\, Y_{Ft-1} + \frac{c}{h}\, (P_M/P_R)_t + \frac{d}{h}\, T .$$

It follows that for model J, the long run coefficient of stock with respect to price is the least squares coefficient of the price variable divided by the least squares coefficient of the lagged stock variable. This is exactly the same coefficient and procedure as used for computing short and long run price responses from model I. Despite the different form of the equations, the estimates of price and income responses are the same. Less emphasis, therefore, need be given to determining whether model I or J is appropriate.

Other models could be presented which are of value in explaining investment behavior. Adjustment and expectation models might be formulated with ending year stock the dependent variable. In this study, it is felt that an explanation of net or gross annual investment provides more information about investment. If we have information about the parameters determining these quantities, inferences can be made about total stock on the basis of models G, H and I, for example.

In subsequent chapters, the expectation and adjustment models are combined. The most successful model combinations are formed by combining relatively simple expectation models illustrated by equations 2, 4, 6, and 8 with the adjustment models G and I.

CHAPTER 8: INVESTMENT IN FARM MACHINERY AND BUILDINGS

In Chapter 8, we apply the concepts and models presented in Chapter 7 to four categories of investment in agriculture: (a) all farm machinery, (b) motor vehicles, (c) machinery other than motor vehicles, and (d) building improvements. Only the portion of investment considered to be used for productive purposes is included. Only 40 percent of automobile purchases are assumed to be associated with the production rather than the consumption (household) sector. Also, the farm operator's dwelling is not included in the productive portion of investment.

The procedure in Chapter 8 is to specify the variables in the empirical equations, then discuss the statistical properties of the estimated investment functions. The empirical equations are used to provide inferences about historic sources of increases in annual investment, price and income elasticities over various periods of time, and finally to project estimates of the annual investment to 1965.

The Demand for All Farm Machinery

The investment market for all farm machinery is estimated by least squares and limited information statistical techniques. The least squares demand equations for all farm machinery are presented first. The demand function was specified in some detail in Chapter 7. Gross annual investment was specified as a function of prices, income, equity, farm size, government programs, the short term interest rate, the level of productive assets and time.

The variables

The variables included in the demand equation are as follows:

Q_{Mt} The dependent variable is a weighted national aggregate of motor vehicle and other machinery purchases for the current calendar year (4). Quantities are weighted by 1935-39 prices prior to 1940; by 1947-49 prices after 1940. Overlapping observations for 1940 are used to value the entire series in millions of 1947-49 dollars. Only the productive portion of the machinery purchases is included. For automobiles, the productive portion is assumed to be 40 percent.

$(P_M/P_R)_t$ The current year index of the ratio of the price of all farm machinery to prices received by farmers for crops and livestock (120). The procedure for weighting prices is given in Chapter 4.

$(P_M/P_{HL})_t$ The current year index of the ratio of the price of all farm machinery to the hired labor wage rate (120).

S_{Mt} The stock of productive farm machinery on January 1 of the current year (4). The variable is in millions of 1947-49 dollars.

S_{pt} The total stock of productive assets on January 1 of the current year (4, 123). The assets include real estate, machinery, livestock, feed, and cash held for productive purposes. The variable is in billions of 1947-49 dollars.

E_{t-1} The past year ratio of proprietors' equities to total liabilities in agriculture (4, 123).

Y_{Ft-1} The net income of farm operators from farming during the past year, deflated by the index of prices paid by farmers for items used in production, including interest, taxes and wage rate (120, 121). Net income includes cash receipts, government payments and non-money income less production expenses.

Y_{DFt-1} The declining three year arithmetic average of Y_F. That is

$$Y_{DFt-1} = \frac{3\ Y_{Ft-1} + 2\ Y_{Ft-2} + Y_{Ft-3}}{6} .$$

G_t An index of government agricultural policies. Years when acreage allotments or production controls are in force are given the value -1. Years when farm prices are supported are assigned values of +1. If supports are fixed, an additional +1 is added. The values are summed to form the index G

(3, 34).

T Time, an index composed of the last two digits of the current year.

The price indices are expressed as a percent of the 1947-49 base, i.e., 1947-49 = 100. All variables are annual data for the U.S. from 1926 to 1959, excluding 1942 to 1947. The observations are chosen as a compromise between a period: (a) short enough that structural changes could be accommodated in the equations, and (b) long enough to allow variations in the structural variables and reasonably precise estimates of the structural parameters. Furthermore, since the variables tend to be less accurately measured in earlier years, the addition of observations prior to 1926 may not add sufficient degrees of freedom to compensate for the increase in error. The years 1942 to 1947 are omitted because the backlog of demand developed during the war years imposed a different demand structure. Perhaps additional postwar years should have been excluded since many would argue that the demand structure had not returned to normal by 1948.

Agricultural machinery other than automobiles has little salvage value outside of the agricultural sector. During depressed economic periods in farming, there are few opportunities to sell machinery to more prosperous sectors because the machines are specialized to agriculture. Furthermore, cycles in other sectors tend to correlate with economic cycles in agriculture, further limiting the sale of unneeded machinery. It follows that the maximum rate of decline of machinery stocks largely is governed by the rate of depreciation during an economic downswing. The limits on stock expansion are not as severe under normal conditions. The optimum estimational approach would be to compute separate demand functions for boom and depression periods. This procedure is not followed in this study, since it would reduce severely the degrees of freedom. Also, gross annual investment was somewhat greater than zero in all years although it was low in the early 1930's. Since gross investment was positive, the assumption that the maximum rate of stock decline did not occur appears to be reasonably met. Hence, the necessity to allow for discontinuous and changing price and income parameters for varying phases of the business cycle appears to be mitigated to some extent.

Changes in the structure of machinery inputs and farm income have been notable since 1926. The quality and size of many farm machines have changed, and a unit of machinery (e.g. tractor) in 1926 is not strictly comparable to a unit in 1959. It is not possible to compensate completely for changes in size or quality in the demand variables. Weighting quantities by prices partially compensates, however, because the improved unit of machinery is weighted by a higher price. The total number of machines may be the same, but the "quantity" weighted by prices is greater if the improvement in quality is reflected in the price.

The farm income structure has changed greatly since 1926. In particular, gross receipts are much greater because resources previously used to provide farm power, seed, etc. are free to produce output for sale. Substitution of non-farm inputs has permitted greater farm product sales but also has added to cash costs. One method of compensating for this structural change is to use net income rather than gross income as the explanatory variable. The increased gross returns from use of purchased resources which once were farm produced is subtracted out, leaving net income of former and latter years somewhat comparable. An additional advantage of using net income is that it reflects annual variations in prices paid by farmers P_P as well as prices received P_R. Use of gross income reflects the influence of P_R only. Summarizing, the net income variable is included in the demand equation to: (a) indicate the earning expectations and financial capabilities of farmers, (b) measure the farmers' expected return on durable resources, (c) correct for structural changes in farm income, and (d) indicate the influence on machinery purchases of P_P and P_R.

Because the dependent variable essentially is a first difference of stocks, the statistical equations are estimated only in original values and logarithms of original values in this chapter.

Least squares demand equations for all machinery

Table 1 indicates the coefficients, standard errors and other statistics of the demand equations for machinery estimated by least squares. Some variables from the economic model are excluded either because they are insignificant (e.g. short term interest rate) or because they are highly correlated with other variables (e.g. cropland per farm).[1]

In equation 24, the coefficients of the variables $(P_M/P_R)_t$, E_{t-1} and T are highly significant. Statistical tests of coefficients indicate that lagged prices, S_p and G do not influence Q_M significantly. It should be remembered that the insignificance of the coefficients does not indicate finally or absolutely that productive assets, labor wages and government programs have no influence on Q_M. There is a high probability that the coefficients of the included form of the variables would occur by chance very often when the variables have no influence on Q_M. But statistical complications such as correlation among variables, observational errors, lack of variation in the data, etc. sometimes cause

[1]Regressions were run including farm size (cropland per farm) and the short term interest rate. The farm size variable was significant, the interest rate variable was not. The equations predicted about as well as those in Table 1 because the farm size variable is highly correlated with other explanatory variables.

Table 1. Demand (annual gross investment) for all farm machinery Q_M es omitting 1942 to 1947; coefficients, standard errors (in pare

Equation, transformation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_M/P_R t	P_M/P_R t-1	P_M/P_{HL} t	P_M t
1-0	B	0.97 0.96	1.86	1954.30	-8.99 (1.59)	0.83 (2.36)		-0 (1
2-0	AB	0.97 0.96	1.47	535.75	-7.66 (1.32)			
2-L	AB	0.97 0.96	1.77	2.27	-1.42 (0.17)			
3-0	B	0.92 0.91	1.23	188.94		-6.91 (2.90)		1 (1
4-0	B	0.97 0.96	1.38	766.78	-8.82 (1.77)		0.41 (1.30)	
5-0	B	0.97 0.96	1.37	852.25	-8.41 (1.18)			
6-0	A	0.95 0.94	1.27	-111.99	-7.98 (1.63)			
6-L	A	0.96 0.95	1.22	2.94	-1.29 (0.18)			
7-0	A	0.96 0.95	1.28	-191.26	-7.46 (1.46)			
7-L	A	0.96 0.95	1.26	3.01	-1.30 (0.19)			
8-0	C	0.97 0.96	1.29	-168.19	-7.57 (1.26)			
8-L	C	0.95 0.94	0.98	3.87	-1.47 (0.19)			

[a]Sources and composition of the dependent variable Q_M and the indi

[b]Equations estimated in original observations are designated by O; in the L equations. Also Y_{DFt-1} in the logarithm equations is the loga are presented in the text.

[c]The Durbin-Watson autocorrelation statistic d'.

all farm machinery Q_M estimated by least squares with annual data from 1926 to 1959, standard errors (in parenthesis) and related statistics are included[a]

	P_M/P_R t-1	P_M/P_{HL} t	P_M/P_{HL} t-1	S_p t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T
	0.83		-0.70	-16.37	98.85					5.45	40.52
)	(2.36)		(1.63)	(11.73)	(33.02)					(6.64)	(11.97)
					100.99		0.030				27.00
)					(27.62)		(0.024)				(5.87)
					-0.41		0.81				0.0218
)					(0.15)		(0.17)				(0.0028
	-6.91		1.51		145.20						26.63
	(2.90)		(1.96)		(36.83)						(12.60)
		0.41			126.01						27.45
)		(1.30)			(20.87)						(7.56)
					124.60						25.99
)					(20.00)						(5.87)
							0.092				42.63
)							(0.022)				(4.94)
							0.57				0.0156
)							(0.16)				(0.0017
							0.056	0.048			39.61
)							(0.023)	(0.018)			(4.54)
							0.59	-0.034			0.0157
)							(0.19)	(0.144)			(0.0018
									0.107		38.62
)									(0.017)		(4.14)
									0.42		0.0167
)									(0.19)		(0.0019

variable Q_M and the indicated independent variables are discussed in the text.

ons are designated by O; in logarithms of original observations by L. The time variable T is in ori, m equations is the logarithm of the simple declining arithmetic average. Expectation and adjustme

ic d'.

es with annual data from 1926 to 1959,
tatistics are included[a]

Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_M t-1	S_M t
				5.45	40.52		
				(6.64)	(11.97)		
	0.030				27.00		
	(0.024)				(5.87)		
	0.81				0.0218		
	(0.17)				(0.0028)		
					26.63		
					(12.60)		
					27.45		
					(7.56)		
					25.99		
					(5.87)		
	0.092				42.63		
	(0.022)				(4.94)		
	0.57				0.0156		
	(0.16)				(0.0017)		
	0.056	0.048			39.61		
	(0.023)	(0.018)			(4.54)		
	0.59	-0.034			0.0157		
	(0.19)	(0.144)			(0.0018)		
			0.107		38.62		
			(0.017)		(4.14)		
			0.42		0.0167		
			(0.19)		(0.0019)		

ables are discussed in the text.

inal observations by L. The time variable T is in original values
eclining arithmetic average. Expectation and adjustment models

Table 1. (Continued)

Equation, transformation and model		R^2 and $\bar{R}^2$	d'	Constant	P_M/P_R t	P_M/P_R t-1	P_M/P_{HL} t	P_M/P_{HL} t-1
9-0	BF	0.97 0.96	1.43	771.38	-7.63 (1.33)			
10-0	F	0.96 0.95	1.41	109.92	-6.69 (1.58)			
10-L	F	0.96	1.19	2.98	-1.28 (0.19)			
11-0	BG	0.97 0.96	1.57	760.25	-8.83 (1.17)			
12-0	G	0.95 0.94	1.26	-122.34	-8.17 (1.75)			
12-L	G	0.97 0.96	1.43	4.06	-1.41 (0.18)			
13-0	H	0.97 0.97	1.86	-648.85	-5.65 (2.10)	4.35 (2.22)		
13-L	H	0.98 0.97	2.04	-0.61	-1.36 (0.29)	0.85 (0.32)		

P_M/P_R t	P_M/P_R t-1	P_M/P_{HL} t	P_M/P_{HL} t-1	S_{ρ} t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1
-7.63					99.83				
(1.33)					(27.95)				
-6.69							0.056		
(1.58)							(0.025)		
-1.28							0.53		
(0.19)							(0.23)		
-8.83					126.01				
(1.17)					(19.35)				
-8.17							0.091		
(1.75)							(0.022)		
-1.41							0.56		
(0.18)							(0.15)		
-5.65	4.35					0.045	0.063		
(2.10)	(2.22)					(0.024)	(0.025)		
-1.36	0.85					0.21	0.70		
(0.29)	(0.32)					(0.20)	(0.20)		

Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_M t-1	S_M t
					23.33	0.15	
					(6.17)	(0.12)	
	0.056				31.39	0.30	
	(0.025)				(6.53)	(0.12)	
	0.53				0.0153	0.030	
	(0.23)				(0.0021)	(0.127)	
					35.20		-0.038
					(7.98)		(0.023)
	0.091				45.36		-0.0099
	(0.022)				(9.69)		(0.0300)
	0.56				0.0202		-0.28
	(0.15)				(0.0027)		(0.13)
0.045	0.063				13.24		0.46
0.024)	(0.025)				(7.72)		(0.12)
0.21	0.70				0.0072		0.29
0.20)	(0.20)				(0.0027)		(0.13)

coefficients of "important" variables to be insignificant.

As discussed previously, E may be regarded as the culmination of the income generating process. Partially as a test of this hypothesis, and to determine if both income and equity are important variables in the demand function, equation 2 includes both E and Y_F. Equation 2 indicates that either variable may be used. The inconsistent signs of variables in equations 2-O and 2-L seems to be caused by (a) the correlation between the income and equity variables, and (b) the inappropriateness of the logarithm transformation.[2] To

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[2]The simple correlation between Y_{Ft-1} and E_{t-1} in original values is -0.87. The matrix of simple correlations between other specified variables in original values O and logarithms L is as follows:

		$(P_M/P_R)_t$	E_{t-1}	T	S_{Mt}
Q_M	O	-0.48	0.95	0.80	0.77
	L	-0.54	0.86	0.75	0.74
$(P_M/P_R)_t$	O	--	-0.30	0.05	-0.08
	L	--	-0.23	0.10	-0.09
E_{t-1}	O	--	--	0.83	0.81
	L	--	--	0.89	0.89
T	O	--	--	--	0.91
	L	--	--	--	0.89

The simple correlation between E and Q_M falls substantially when the variables are transformed to logarithms. The relationship between Q_M and E appears to be linear in original values. The insignificance of the coefficient of E in the logarithm equations is ascribed to a situation where the logarithm transformation is not appropriate. It should be noted that the time variable T is always in original values.

alleviate this difficulty, in later equations either income or equity (never both variables) is included. The logarithm transformation does not reflect the influence of E, hence, equations involving this variable are estimated only in original values.

Equations 3 and 4 are estimated to determine the importance of wages in the demand for machinery without complications caused by other variables. Again the coefficients of wages are insignificant, perhaps because machinery prices and wage rates have tended to move similarly through time. The two equations also provide some basis for evaluating the relevance of current or past prices in the demand function. The magnitude and significance of the current variable P_M/P_R are greater, the R^2 is higher and the tendency for autocorrelations, indicated by d', is less apparent in equation 4. In short, equation 4 appears to be more appropriate. Past prices are important, but the influence of past values of P_R and resource prices tend to enter through the current price and income or equity variables. Equation 3 with only lagged values of the predetermined variables is useful for predicting machinery purchases in the coming year since $(P_M/P_R)_t$ is unknown. The prediction may be biased if the current price is important -- as equation 4 indicates. As a possible improvement over the results suggested by equations 3 and 4, the ratio of <u>current</u> machinery price and <u>lagged</u> prices received by farmers P_{Mt}/P_{Rt-1} was included in a least squares equation with other explanatory variables E and T. The magnitude and significance of the coefficient of the price variable P_{Mt}/P_{Rt-1} were lower than similar quantities in equation 5, and the modified price was rejected in favor of current price. The current price ratio must be interpreted as representing some influence of past prices.

The three variables in equation 5 explain 97 percent of the variation about the mean of Q_M, and the coefficients of each are highly significant. The test of the null hypothesis that the residuals are uncorrelated is inconclusive. Model B, employing variable E which is a measure of farmers' financial position and a proxy variable representing income expectations, apparently is useful for expressing demand for farm machinery.

The remaining equations in Table 1 are included to evaluate the relevance of other distributed lag models. Equations 6 and 7 are model A with income lagged one and two years, respectively. The logarithm transformation indicates that income before the past year is not important in determining demand for machinery. But the coefficient of Y_{Ft-2} in equation 7-0 is significant at approximately the 99 percent level of probability. The magnitudes of the coefficients in equation 7-0 indicate that incomes prior to the year t-2 may also influence current demand. It seems appropriate to assume some structure of the coefficients permitting estimation of the lag with fewer variables. Equation 8 is model C, where Y_{DFt-1} is a declining three year average of farm income. The coefficient of the variable is highly significant in equation 8-0, and is slightly larger than the combined coefficients of the two income variables in equation 7-0. The R^2 is increased by each additional income variable in equations 6-0, 7-0 and 8-0, and the last equation appears to be the "best". The statistical properties and the performance of the coefficients under changing conditions suggests that the equations estimated in original values are more appropriate than those estimated in logarithms for introducing income lags into machinery demand functions. Equation 5-0 (model B) and equation 8-0 (model C) display similar properties and are useful for expressing machinery demand.

Equations 1 to 8 essentially are expectation models. The appropriateness of the adjustment models F, G and H may be judged from equations 9 to 13. Equation 9 combines expectation model B and adjustment model F. The insignificance of the coefficient of Q_{Mt-1} suggests that the adjustment model is inappropriate for <u>annual</u> gross investment. That is, farmers adjust purchases to the desired or equilibrium level in the short run if they are subjectively certain of favorable prices, income and other explanatory variables. Equation 10 indicates that if expectations are not adequately represented in the model, the adjustment coefficient may be significantly different from unity.

It is well to remember that although annual investment in machinery is adjusted to the desired level in the short run as indicated by equation 9, it may still take a long time to reach the desired level of stock. Thus, models B and G are combined to estimate the adjustment to the desired level of stocks. The coefficients of equations 11 and 12-O are insignificant, indicating the adjustment coefficient g and depreciation rate h are both zero or are equal to each other. Since the depreciation rate is known to lie somewhere between 0.15 and 0.25, the adjustment coefficient g is also expected to be within that range. Equation 12-L presents a different result and indicates that the adjustment coefficient is somewhat larger. Equation 12-L appears to be less acceptable than equation 11, because expectations and financial circumstances are more adequately considered in the latter.

It is interesting to note that if $g=h$ as indicated by equation 11 and 12-O, omission of lagged stock from the investment function causes few statistical complications. That is, equations such as 5 and 8 may be very satisfactory expressions of machinery demand.

The R^2 is large and autocorrelation is insignificant in the adjustment model H (equation 13). The positive sign of the past year price variable $(P_M/P_R)_{t-1}$ is not consistent with logic, however, and the adjustment coefficient 0.54 in equation 13-O is inconsistent with estimates of g in equation 11 and 12-O.

Of the equations in Table 1, several might be chosen to represent adequately the demand for farm machinery. The models which assume net farm income to be an expectational variable appear particularly appropriate, especially when the equations are estimated in original data. In most instances, the logarithm equations give less plausible results based on the size of the R^2, d' and a priori knowledge of the coefficients. It is possible to specify several reasons for this result. The linear demand function is consistent with a quadratic production function which some studies indicate is more appropriate than logarithm production functions for expressing physical relationships in agriculture (115). Some error may be introduced because the expectation variables are logarithms of simple arithmetic aggregates rather than the sum of logarithms in the "L" equations. Another specification and aggregation procedure might improve the comparability of the estimates from different transformations. A plausible explanation for the more favorable estimates from equations estimated from untransformed data is that a specification linear in the original observations approximates the nature of the demand relationship rather well in the particular period studied. Selection of a different period might reveal advantages of other transformations.

<u>Limited information demand equation for all farm machinery</u>

When demand for all farm machinery is estimated as part of an interdependent market structure with other farm resources and farm output, the result is equation 14.

$$(14)\quad Q_{Mt} = 11907 - \underset{[-5.7]}{90.1}\, P_{Ot} - \underset{[-0.3]}{5.0}\, P_{Mt} - \underset{[-2.9]}{59.2}\, P_{HLt} + \underset{[3.4]}{70.8}\, P_{Rt}$$
$$- \underset{[-4.3]}{113.9}\, N_t - \underset{[-0.15]}{1.7}\, (P_M/P_R)_{t-1} + \underset{[0.8]}{197.0}\, E_{t-1}$$
$$+ \underset{[2.8]}{66.3}\, r_{St-1} - 6.6\, T\ .$$

The demand quantity Q_M, the number of farms N, and the prices of operating inputs P_O, machinery P_M, hired labor P_{HL}, and farm output P_R are endogenous variables. The equity ratio E, short term interest rate r_S, time T and $(P_M/P_R)_{t-1}$ are regarded as predetermined variables. The variable r_S is coded as 100 times the short term interest rate. The price variables are adjusted to a 1947-49 base and are deflated by the implicit price deflator of the gross national product (128). The data extend from 1926 to 1959, omitting 1942 to 1945. Rather than sacrifice the data for 1946 and 1947 in the entire model because the backlog of demand for machinery had not been filled, the data for machinery are "corrected" for the condition by using predicted values of Q_M for 1946 and 1947 from a single equation, least squares demand function. Standard errors were not computed for equation 14. Elasticities are included in brackets below the coefficients of all variables except time T to aid in interpretation of the results.

The equation substantiates the results of the least squares functions -- that the current price of machinery is more important than lagged price. The elasticity of machinery demand with respect to farm numbers N is -4, indicating that a one percent decrease in farm numbers tends to be associated with a four percent increase in machinery sales. The result implies a large substitution of machinery for labor as acreage per farm increases. However, the negative sign of the farm wage rate P_{HL} coefficient indicates, perhaps incorrectly, that labor and machinery are short run complements. The signs of the P_O and P_R coefficients are as expected, but the magnitudes of the coefficients are unusually large.

Of the predetermined variables, the equity ratio appears to be quite important; the coefficient is larger than in the least squares equation 5. The sum of the P_M coefficients -6.7 is slightly less (absolute value) than the coefficient of price -8.4 in equation 5. The signs of the r_S and T coefficients in the equation conflict with a priori considerations. The slowly changing r_S variable could have absorbed the influence of the time trend and vice versa.

The general conclusion is that the limited information equation 14 is less acceptable than the least squares equations for expressing machinery demand. The signs and magnitudes of the coefficients in equation 14 are questionable in several instances. The standard errors were not computed, but the large size of some of the questionable coefficients indicates that they may be significant. In future computations of price elasticities and analysis of changes in demand quantities through time, we rely heavily on the single equation results.

The limited information equation 14 may be less satisfactory than the least squares equation for expressing machinery demand because of the nature of the identification process (for rule of identification, see Tintner (113)). Those equations in the simultaneous model which are of greatest interest to the researcher tend to be specified in detail. Equations of least interest tend to be specified less fully. But the conditions for identification indicate that the tendency for underidentification is most likely to be found in the equations including the greatest number of variables (most adequately specified). Unwittingly, the researcher gets less satisfactory results from the equations in which he has greatest interest because of a tendency for underidentification. Also, some difficulties may arise because of multicollinearity when many variables are specified in the equation.

Price and income elasticities of demand for all machinery

Table 2 illustrates the elasticities of demand for annual purchases Q_M and stock S_M with respect to prices and expected income from selected equations in Table 1. The elasticity of annual investment with respect to P_M or P_R approximately is unitary in the short run. The percentage increase in stock is less than one-fourth this amount because of the greater initial quantity. P_M essentially is a short run variable and is not assumed to be a part of expectations, hence, the elasticity of Q_M with respect to P_M is the same in the short and long run.

Because of the importance of P_R in Y_F, the long run elasticity of Q_M with respect to P_R is greater than the short run elasticity. Two equations are needed to translate E in equations 5 and 8 into P_R. The equations containing E but not Y_F can be translated by assuming that E is generated from past income. To determine the relationship between income and equity, the following least squares equation 15 was computed from logarithms of annual data extending from 1926 to 1941 and 1946 to 1959. Equity is estimated as

$$(15)\quad E_{t+1} = -5.57 + \underset{(0.24)}{0.71}Y_{Ft} + \underset{(0.24)}{0.86}\, Y_{DFt-1}, \qquad R^2 = 0.80$$

a function of net income Y_F and a declining average of net income Y_{DF}. The equation indicates that a sustained rise of one percent in net income will increase the equity ratio 1.57

Table 2. Elasticities of demand for annual investment in machinery Q_M and for machin
computed from the equations in Table 1[a]

Equation, transformation and model[b]		Elasticity of Q_M with respect to: P_M[c] Short run (1-2 years)	Y_F^* [d]	P_R Short run[e] (1-2 years)	P_R Long run[f] (3-4 years)	P_M Short run[g] (1-2 years)	Lon (man
5-0	B	-0.79	0.79	0.79	2.37	-0.18	-
8-0	C	-0.71	0.74	0.71	2.19	-0.16	-
8-L	C	-1.47	0.42	1.47	2.31	-0.33	-
11-0	BG	-0.83	0.80	0.83	2.43	-0.19	-

[a]See the text and Table 1 for discussion of data, methodology, coefficients, sta

[b]Elasticities for data in original values are computed at the means.

[c]Computed from the coefficient of current price $(P_M/P_R)_t$.

[d]Computed from the sum of lagged income coefficients. The equity ratio E rather
coefficient of E was translated into elasticities with respect to Y_F by the least squa

$$\text{(a)}\quad E_{t+1} = -5.57 + \underset{(0.24)}{0.71}\, Y_{Ft} + \underset{(0.24)}{0.86}\, Y_{DFt-1} \qquad R^2 = 0.80$$

where E_{t+1} is the January 1 equity ratio, Y_F is net farm income and Y_{DF} is a declining
in logarithms from 1926 to 1941 and 1946 to 1959.

[e]Computed from the price variable $(P_M/P_R)_t$.

[f]The sum of the short run elasticity plus the component P_R of Y_F^*, assumed to be
Appendix B. For equation 8-0, the elasticity is 0.71 + (2.0)(0.74) = 2.19.

[g]Found by multiplying the elasticity of Q_M with respect to $(P_M/P_R)_t$ by the ratio

[h]The short run elasticity divided by the adjustment coefficient 0.20. The adjust
depreciation rate according to equation 11-0. The USDA (121, 123) estimated the machi
year stocks for each of the six years from 1955 to 1960.

[i]Found by multiplying the ratio of means by the elasticity of Q_M with respect to
after Q_M has been increased to the desired level.

[j]The intermediate run elasticity divided by the assumed adjustment coefficient, a
the maximum level of stock achieved after an increase in P_R, and may not be reached fo
approximately 90 percent of the total adjustment will be completed in 10 years.

nery Q_M and for machinery stocks S_M with respect to price and net farm income

	Elasticity of S_M with respect to:					
	P_M			P_R		
)	Short run[g] (1-2 years)	Long run[h] (many years)	Y_F^*	Short run[g] (1-2 years)	Intermediate run[i] (3-4 years)	Long run[j] (many years)
	-0.18	-0.90	0.18	0.18	0.54	2.70
	-0.16	-0.80	0.17	0.16	0.49	2.45
	-0.33	-1.65	0.10	0.33	0.52	2.60
	-0.19	-0.95	0.18	0.19	0.55	2.75

gy, coefficients, standard errors and related statistics.

he means.

equity ratio E rather than income was included in equations 5 and 11. The
o Y_F by the least squares regression

0.80

and Y_{DF} is a declining three year average of Y_F. The variables are annual data

of Y_F^*, assumed to be twice the income elasticity based on the results of
74) = 2.19.

$(P_M/P_R)_t$ by the ratio of mean of Q_M to S_M.

ient 0.20. The adjustment coefficient approximately is equal to the
3) estimated the machinery depreciation to be 0.19 percent of beginning

of Q_M with respect to P_R. This is the approximate response in total stock

ustment coefficient, as indicated in footnote h. The long run elasticity is
may not be reached for several years. If the adjustment coefficient is 0.20,
ed in 10 years.

percent. Since the elasticity of Q_M with respect to E in equation 5 is 0.50, the elasticity with respect to Y_F approximately is (0.50)(1.57) = 0.79. The result is reassuringly similar to the results of equation 8-0 in which income was directly included. The implication is that model B is a relevant proxy variable for net income in the investment function.

A definitional equation relating net income to P_R/P_P is presented in Appendix B and provides a useful basis for translating net income into price elasticities. The equation indicates that the average elasticity of net income with respect to P_R/P_P is 2.0. Therefore the elasticity of Q_M with respect to P_R computed from the income component of equation 5 approximately is (2.0)(0.79) = 1.58. The total long run elasticity of Q_M with respect to P_R is therefore 0.79 (due to P_M/P_R) plus 1.58 (due to E), or 2.37. The result agrees favorably with the estimates of other equations and indicates that a one percent increase in P_R tends to raise annual investment slightly more than two percent in the long run. Some disparity exists between the original value and logarithm equations in allocating the influence of P_R in P_M/P_R and Y_F. Since the logarithm equation tends to allocate more influence to P_M/P_R and less to Y_F, the short run elasticity is greater in equation 8-L, but the long run elasticities are surprisingly similar between transformations.

Once the desired level of annual purchases is reached, the stock of machinery continues to grow until gross investment equals depreciation. The maximum level (long run) of stocks is reached much later than the maximum (long run) level of annual investment. The estimates of stock elasticities in Table 2 are computed basically from the annual investment elasticities. The ratio of the investment mean to the stock mean was multiplied by the annual investment elasticities to form the short and intermediate run stock elasticities. The long run elasticity is based on equations 11-0 and 12-0, which indicate that the adjustment and depreciation rates are approximately equal. From knowledge of the depreciation rate, the adjustment rate is assumed to be 0.20. The results indicate that stock is relatively unresponsive to changes in price in the short and intermediate run. The analysis indicates that a one percent rise in prices received P_R tends to raise stock only one-fifth of one percent in the first one or two years, but after several years may increase stock between two and three percent.[3] The length of time required to reach this

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[3]The number of years N required for a specified proportion A of total adjustment, given the adjustment rate g is

$$N = \frac{\log(1-A)}{\log(1-g)} .$$

If a = 0.9, g = 0.2, then N = 10. That is, 10 years are required to make 90 percent of the adjustment to the equilibrium level of machinery stock. The number of years required for the adjustment of stock is (continued on next page)

percentage depends on the adjustment rate. Because of the historic volatility of P_R, a major portion of the past variation in investment activity has been closely associated with farm output price P_R.

The elasticity with respect to a third price variable P_P (prices paid by farmers for items used in production, including interest, taxes and wage rates) may be computed but is not included in Table 2. Although labor and other input prices are not explicitly included in the functions, they are components of P_P through net income. The elasticity of either Q_M or S_M with respect to P_P is roughly -1.5 in the long run. The implication is that other inputs are net complements of machinery in the market. The elasticity is negative because an increase in input prices reduces the surplus of income available for machinery purchases. This result does not preclude the existence of substitutes for machinery, notably labor, in the market. It only indicates the net influence of input prices P_P.

It is well to compare these estimates with results from other studies. Cromarty's (23, p. 40) least squares estimates

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(footnote continued from previous page) conservative because the formula assumes the annual investment is at the equilibrium level. Because three or four years are required for annual investment to reach this level, an adjustment may be made in the time required to reach the equilibrium level of stock by adding two or three years to N above.

of short run demand elasticities for machinery purchases with respect to P_M is -1.0, P_R is 0.7. His results agree quite closely with those of this study. Cromarty makes no estimate of long run elasticities, but if we use the above estimate to translate income elasticity to price elasticity, the long run elasticity of annual purchases with respect to P_R is 0.7 plus (2.0)(0.5) = 1.7. His study also includes farm assets as an explanatory variable, and if the P_R influence on assets is included, the total elasticity might be very near the estimates of this study.

The limited information demand equation 14 indicates that demand elasticity of Q_M with respect to P_M is -0.5. The elasticity of the same quantity with respect to P_R is 3.6 without consideration of E. If the influence of P_R on E were also included, the elasticity would be unusually large and quite unrealistic.

The actual proportion of the total change in machinery purchases attributed to price and income over time depends on the historic movements of the variables as well as on the coefficients and elasticities. The equations in Table 1 provide the basis for evaluating the extent of the actual change in demand quantities over a specified time period attributable to prices P_R/P_M, income Y_F and slowly changing influences of technology, knowledge, etc. represented by the time variable T. This investigation of historic sources of the increased demand for machinery in the U.S. from 1926 to 1959 is postponed until the final section of the chapter.

Trends and projections in all machinery purchases

Figure 1 indicates that demand for farm machinery is considerably more volatile and displays a different trend than the demand for operating inputs. The figure illustrates graphically the quantitative results in Table 2 -- that machinery purchases are more sensitive than operating input purchases to changes in prices received by farmers. Machinery purchases fell sharply in the depression years and again in 1938 when farm output prices dropped appreciably. Improved machinery, new models, favorable prices and other factors undoubtedly contributed to the large amount of purchases in the late 1940's. As the backlog of machinery orders were filled and farm income declined, demand for machinery began to fall in the 1950's. The downward trend in machinery demand during the postwar era shows few signs of reversal according to the actual observations in Figure 1.

Equation 8-0 predicts the actual observations quite well, but unfortunately there are rather large errors in recent years, i.e. 1956 and 1957. Also, the extrapolated value for 1960 considerably overestimates the actual quantity. The actual quantity is a preliminary estimate, and later revisions may reduce the prediction error. The machinery purchases

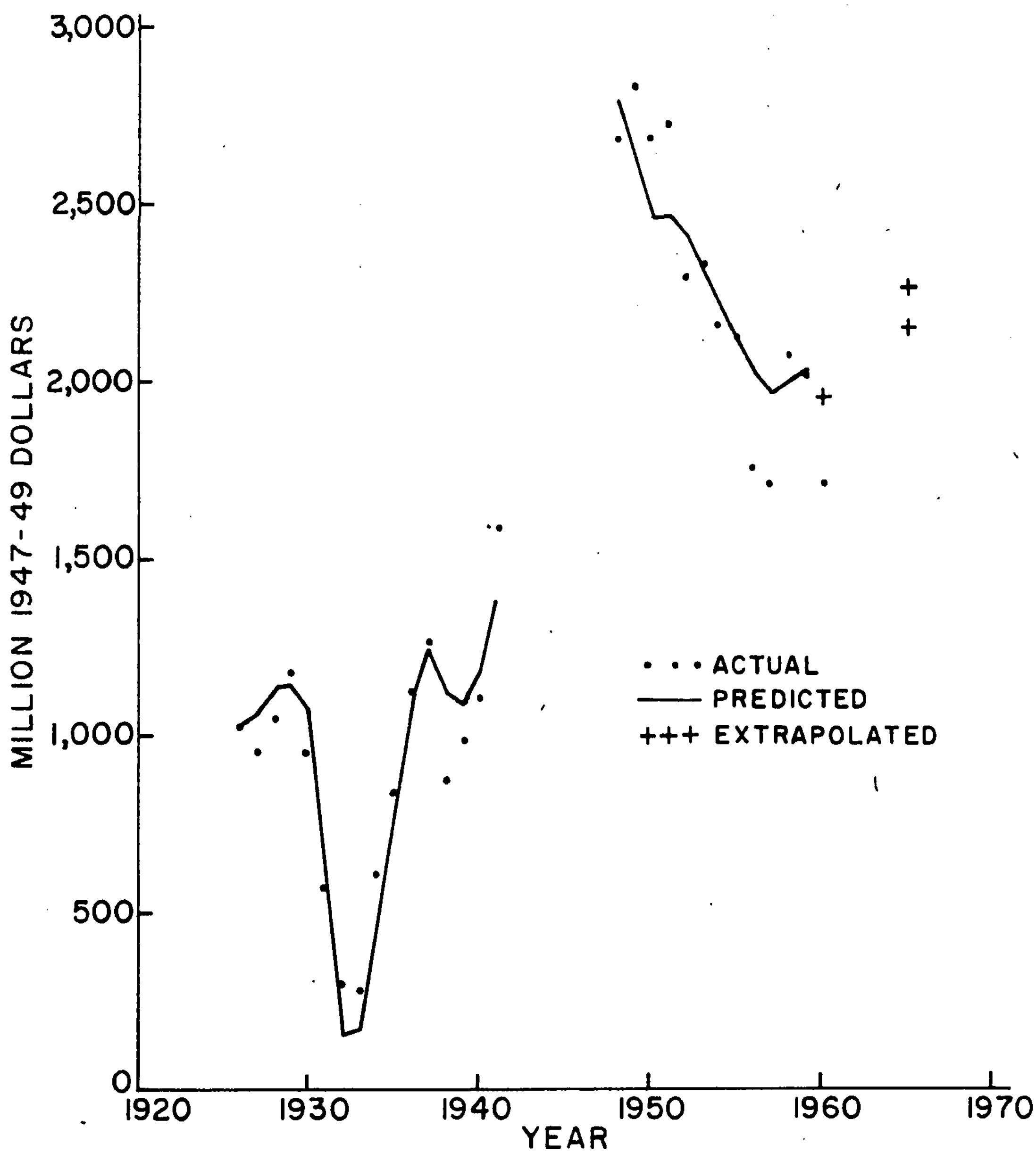

Figure 1. Trends in purchases of all farm machinery Q_M from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 8-0

projected for 1965 depend on the assumed values of the independent variables -- prices and net farm income. The higher estimate is made from equation 8-0 assuming income and prices will be at 1955-59 average values in 1965. Because the price of machinery has tended to increase relative to prices received by farmers, the second, lower prediction is made assuming $(P_M/P_R)_t$ will be 10 percent greater in 1965 than in 1955-59, but that net farm income will remain at the 1955-59 level. The two estimates indicate that by 1965 the quantity will be respectively 15 and nine percent greater than the predicted 1960 level. Based on past trends, the price of machinery is expected to increase by 1965, hence, the lower prediction is more realistic. That is, annual gross investment in machinery is expected to increase nine percent above the predicted 1960 level by 1965. Whether these projections are realized depends to a large extent on the value of P_R since it is the most volatile element in both the price and income variables.

The equations in Table 1 indicate that demand increases from two or more percent per year (from the coefficient of T) aside from changes in prices and income. Hence, demand in 1965 could be expected to be greater than in the 1955-59 period even though prices and income remain unchanged. The projections imply that the downward postwar trend in purchases will be reversed. Since the value of Q_M projected for

1965 depends heavily on the underlying assumptions about the values of explanatory variables, the reader may wish to note the influence on demand quantity of alternative assumptions about prices and incomes for 1965.

Supply of all farm machinery estimated by limited information

The decoded supply equation for all farm machinery is

$$(16)\quad P_{Mt} = \underset{}{-18.75} + \underset{(0.0084)}{0.0218\, Q_{Mt}} + \underset{(0.27)}{0.93\, P_{ISt}} - \underset{(0.17)}{0.32\, C_t}$$

where P_M is defined as previously, P_{IS} is the wholesale price of iron and steel (30) and C is a structural variable with a value of zero in each prewar year; 100 in each postwar year. Prices are deflated by the general price deflator of the gross national product, and are adjusted to make 1947 to 1949 equal 100. The annual data extend from 1926 to 1941 and 1946 to 1959. To adjust for the latent demand in 1946 and 1947, values of Q_M predicted by a least squares equation, estimated without the two years, were used as observations in the simultaneous model for 1946 and 1947.

The price elasticity of machinery supply computed from equation 16 is 2.92. The coefficient of Q_M is more than twice the standard error (in parenthesis) and probably is not equal to zero. The coefficient indicates the price flexibility, and if it is near zero the supply elasticity is very large. The approximate confidence limit for price elasticity is computed from the inverse of two standard deviations on each side of the price flexibility coefficient. Estimated by the procedure at the means, the confidence interval for price elasticity of supply is 1.8 to 4.1. The estimate indicates that the elasticity of short run machinery supply is very high but not infinite. In an earlier, slightly modified structural model containing the same variables as in equation 16 but with actual rather than predicted values of Q_M for 1946 and 1947, the coefficient of Q_M was smaller than the standard error. The result was consistent with the hypothesis that machinery supply is perfectly elastic. Although equation 16 indicates supply is less than perfectly elastic, it does indicate that price is relatively unresponsive to quantity changes in the short run.

That farmers are price takers (quantity a function of price) and manufacturers are price setters (price a function of quantity) should not be inferred from the limited information equations because of the normalization on quantity in equation 14 and price in equation 16. The limited information coefficients are independent of the direction of normalization -- the results would have been the same if the equations would have been normalized on other endogenous variables.

The variable most significantly explaining machinery price is P_{IS}. A one percent increase in iron and steel price raises machinery price one percent according to equation 16.

The result is not surprising -- steel is an important raw material in farm machinery. Because non-farm wage rates affect the cost of steel production, the wage rate tends to be reflected in the price of iron and steel.

The real price (relative to all prices of goods and services in the U.S. indicated by the deflator for the GNP) has declined in the postwar period according to the coefficient of C in equation 16. The decline may not be significant; the coefficient is less than twice the standard error.

Demand for Motor Vehicles Estimated by Least Squares

The specification of the demand for motor vehicles is similar to the previous specification of demand for all farm machinery. Variables considered to be important influences on demand quantities are motor vehicle prices, prices received by farmers, wages paid for hired farm labor, stocks of assets, net farm income, the equity ratio, government programs and time. The logic of the specification and the nature of expectations and adjustments are similar to those discussed previously in this chapter and in Chapter 7.

The variables

Variables peculiar to the demand functions for motor vehicles are:

Q_{MVt} — The dependent variable is a weighted two-price aggregate of motor vehicle purchases during the current calendar year (4). The variable includes tractors, trucks and the productive portion of automobile purchases, assumed to be 40 percent. The procedure for weighting the quantities is discussed in the previous section on all farm machinery. The variable is expressed in millions of 1947-49 dollars.

$(P_{MV}/P_R)_t$ — The current year index of the ratio of prices paid by farmers for motor vehicles to prices received by farmers for crops and livestock (120).

$(P_{MV}/P_{HL})_t$ — The current year index of the ratio of prices paid by farmers for motor vehicles to the hired labor wage rate on farms (120).

The remaining variables specified in the demand function S_p, E, Y_F, Y_{DF}, G and T are discussed in the previous section on all farm machinery. The variables are annual data for the U.S. from 1926 to 1959, omitting 1942 to 1947. All price indices are expressed as a percent of the 1947-49 average.

The estimated demand equations

Coefficients, standard errors and related statistics for motor vehicle demand equations presented in Table 3 are very similar to the results in Table 1. The price of motor

Table 3. Demand (annual gross investment) functions for motor vehicles Q_{MV} esti
omitting 1942 to 1947; coefficients, standard errors (in parenthesis)

Equation, transformation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_{MV}/P_R t	P_{MV}/P_R t-1	P_{MV}/P_{HL} t	P_{MV}/P_{HL} t-1	
17-0	B	0.95	2.16	1332.91	-5.77	0.95		-0.04	-1
		0.93			(1.21)	(1.78)		(1.28)	(
18-0	AB	0.93	1.57	335.94	-4.33				
		0.92			(1.09)				
18-L	AB	0.93	1.52	2.33	-1.15				
		0.92			(0.21)				
19-0	B	0.88	1.39	-27.09		-3.97		1.68	
		0.86				(2.03)		(1.33)	
20-0	B	0.94	1.64	235.61	-6.11		1.35		
		0.93			(1.40)		(1.00)		
21-0	B	0.93	1.51	490.84	-4.72				
		0.92			(0.97)				
22-0	A	0.91	1.43	-24.51	-4.55				
		0.90			(1.21)				
22-L	A	0.92	1.43	2.77	-1.08				
		0.92			(0.21)				
23-0	A	0.93	1.46	-63.32	-4.25				
		0.91			(1.16)				
23-L	A	0.93	1.47	2.88	-1.09				
		0.91			(0.22)				
24-0	C	0.93	1.47	-51.38	-4.31				
		0.93			(1.04)				
24-L	C	0.92	1.28	3.51	-1.22				
		0.91			(0.21)				

[a]Sources and composition of the dependent variable Q_{MV} and the indicated in

[b]Equations estimated in original observations are designated by O; in logari
original values in the L equations. Also Y_{DFt-1} in the logarithm equations is th
and adjustment models are presented in the text.

[c]The Durbin-Watson autocorrelation statistic d'.

functions for motor vehicles Q_{MV} estimated by least squares with annual data from 1
nts, standard errors (in parenthesis) and related statistics are included[a]

$_{MV}/P_R$ t	P_{MV}/P_R t-1	P_{MV}/P_{HL} t	P_{MV}/P_{HL} t-1	S_p t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_1 t·
5.77	0.95		-0.04	-14.39	60.17				
1.21)	(1.78)		(1.28)	(8.71)	(23.43)				
4.33					56.36		0.015		
1.09)					(21.48)		(0.019)		
1.15					-0.23		0.59		
0.21)					(0.19)		(0.22)		
	-3.97		1.68		91.21				
	(2.03)		(1.33)		(23.41)				
6.11		1.35			72.62				
1.40)		(1.00)			(15.20)				
4.72					68.66				
0.97)					(15.17)				
4.55							0.050		
1.21)							(0.015)		
1.08							0.44		
0.21)							(0.18)		
4.25							0.030	0.026	
1.16)							(0.017)	(0.013)	
1.09							0.48	-0.059	
0.22)							(0.21)	(0.165)	
.31									0.0
.04)									(0.0
.22									0.3
.21)									(0.2

lent variable Q_{MV} and the indicated independent variables are discussed in the text.

vations are designated by O; in logarithms of original observations by L. The time
$_{DFt-1}$ in the logarithm equations is the logarithm of the simple declining arithmetic
text.

tistic d'.

least squares with annual data from 1926 to 1959,
ted statistics are included[a]

E $_{t-1}$	Y_F $_t$	Y_F $_{t-1}$	Y_F $_{t-2}$	Y_{DF} $_{t-1}$	G $_t$	T	Q_{MV} $_{t-1}$
0.17					2.82	27.38	
3.43)					(4.71)	(8.96)	
6.36		0.015				15.31	
1.48)		(0.019)				(4.73)	
-0.23		0.59				0.0189	
0.19)		(0.22)				(0.0037)	
1.21						14.46	
3.41)						(8.43)	
2.62						19.39	
5.20)						(5.68)	
8.66						14.87	
5.17)						(4.67)	
		0.050				24.15	
		(0.015)				(3.71)	
		0.44				0.0153	
		(0.18)				(0.0021)	
		0.030	0.026			22.40	
		(0.017)	(0.013)			(3.61)	
		0.48	-0.059			0.0155	
		(0.21)	(0.165)			(0.0022)	
				0.058		21.90	
				(0.013)		(3.40)	
				0.32		0.0164	
				(0.20)		(0.0023)	

variables are discussed in the text.

original observations by L. The time variable T is in
thm of the simple declining arithmetic average. Expectation

Table 3. (Continued)

Equation, transformation and model		R^2 and $\bar{R}^2$	d'	Constant	P_{MV}/P_R t	P_{MV}/P_R t-1	P_{MV}/P_{HL} t	P_{MV} t
25-O	BF	0.93 0.92	1.61	458.87	-4.41 (1.11)			
26-O	F	0.92 0.91	1.64	37.46	-3.92 (1.28)			
26-L	F	0.93 0.91	1.41	2.72	-1.12 (0.22)			
27-L	H	0.95 0.94	2.30	-0.64	-1.17 (0.35)	0.73 (0.38)		

Constant	P_{MV}/P_R t	P_{MV}/P_R t-1	P_{MV}/P_{HL} t	P_{MV}/P_{HL} t-1	S_p t	E t-1	Y_F t	Y_F t-1	Y_F t-2
458.87	-4.41 (1.11)					61.18 (19.79)			
37.46	-3.92 (1.28)							0.037 (0.018)	
2.72	-1.12 (0.22)							0.54 (0.25)	
-0.64	-1.17 (0.35)	0.73 (0.38)					0.25 (0.24)	0.71 (0.24)	

E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_{MV} t-1
61.18						13.70	0.095
(19.79)						(5.12)	(0.159)
		0.037				19.31	0.22
		(0.018)				(5.12)	(0.16)
		0.54				0.0163	-0.098
		(0.25)				(0.0027)	(0.167)
	0.25	0.71				0.0085	0.11
	(0.24)	(0.24)				(0.0033)	(0.17)

vehicles relative to prices received in the current year is the most significant price variable (equations 17, 19, 20). According to equation 18, either income or equity, but not both variables, need be specified in a given demand equation. One possible reason for the insignificance of S_p in equation 17 is that the variable is highly correlated with motor vehicle stock and the coefficient may be zero because of compensating influences of the adjustment and depreciation coefficients (cf. model G). The coefficient of G in equation 17 and of P_{MV}/P_{HL} in equations 17, 19 and 20 do not suggest that farm wage rates and government programs have played significant roles in the rising demand for farm machinery. The coefficients of the three independent variables in equation 21-0 are highly significant. Together the variables explain 93 percent of the annual variation in motor vehicle purchases.

The influence of additional lagged values of net income may be observed in equations 22-0, 23-0 and 24-0. The magnitude of the sum of income coefficients increase from 0.050 to 0.056 to 0.058 as successive income variables are included in the respective equations. The small increments in the magnitude of the coefficient and R^2 imply that additional income lags beyond t-3 would improve the equation very little.

The insignificant coefficients of the lagged quantities Q_{MVt-1} in adjustment equations 25 and 26 imply that farmers do not delay in adjusting annual purchases to desired levels after they have become convinced that price and income conditions are favorable. The adjustment coefficient for annual gross investment in motor vehicles is not significantly different from unity, indicating that the adjustment form is not needed to express annual purchases. This does not imply that total stocks are adjusted to equilibrium levels in the short run also. Additional adjustment models such as G with beginning year stocks were not estimated. But adjustment model H, estimated only in logarithms, is included (equation 27). The coefficient of lagged motor vehicle quantity is non-significant. The R^2 is high, but the sign of the lagged price is inconsistent with a priori considerations and leads one to question the appropriateness of the model. One difficulty embodied in adjustment model H is the importance of P_R in the four price and income variables. Because this common component of several variables tends to create collinearities, the regression law is unable to allocate the relative influence of each variable.

The conclusion from Table 3 is that gross annual investment in productive motor vehicles can be expressed simply by the current price $(P_{MV}/P_R)_t$, time T and by one or more variables such as E or Y_F expressing the financial structure in the demand function. Some difficulties in interpretation arise because of inconsistencies between equations estimated in original values and in logarithms. In some respects each is an acceptable form and the degree of autocorrelation in the residuals, indicated by d' does not appear to be high in the equations. The equations estimated in original values appear to indicate the anticipated influence of past income on machinery purchases more adequately, however.

Demand for motor vehicles was estimated as a function of current price, past year income, cropland per farm, the short term interest rate and time. The coefficient of the short term interest rate was highly insignificant. The coefficient of the farm size variable was significant and negative. Because farm size is highly correlated with other variables, it was not retained in the equation. Current year machinery prices may be known and current year prices received unknown when machines are purchased. The ratio of current machinery price to past year prices received was included in the demand equation with other explanatory variables E and T. This price variable was considered inferior to current price and was not retained in subsequent equations.

Price and income elasticities of demand for motor vehicles

The pattern of demand elasticities for motor vehicles Q_{MV} is similar to that depicted for all machinery in Table 2. The elasticities appear to be slightly lower for motor vehicles, however. Based on equations 23-0 and 24-0, the price elasticity of demand with respect to $(P_{MV}/P_R)_t$ is -0.64.

The demand elasticity with respect to Y_F computed from the same equations is 0.66. Using the definitional equation 1, Appendix B, to translate income to price elasticity, the elasticity of Q_{MV} with respect to P_P is $-(2.0)(0.66) = -1.32$, and with respect to P_R is 0.64 plus 1.32, or 2.0 in the long run. Similarly, the respective total elasticities of Q_{MV} with respect to P_M, P_P and P_R from equation 23-L are -1.1, -0.84 and 1.9. It appears that the unstability in relative magnitudes of the price and income elasticities between the original value and logarithm equations may arise from the importance of P_R in the variables. The logarithm equation indicates a heavier weight for current price; the original value equations a heavier weight for income (past price). But the total, long run elasticity of Q_{MV} with respect to P_R approximately is 2.0 for both forms.

Because mean annual purchases are approximately one-fourth of the mean stock of motor vehicles, the percent increase in stock from a one percent increase in P_{MV}/P_R is $(0.25)(-0.64) = -0.16$ based on equations 23-0 and 24-0. The elasticity of stock at the time (three or four years) when annual purchases have reached the desired level is referred to as the intermediate elasticity of stock. It is approximately $(0.25)(2.0) = 0.5$ with respect to P_R according to the above equations. If we assume the adjustment coefficient is 0.2, the long run elasticity of stock with respect to P_R is

0.5/0.2 = 2.5. If 0.2 is the correct adjustment rate, approximately 10 years are required to make 90 percent of the adjustment to the long run level of stock. The one percent increase in P_R is assumed to be sustained through the entire period, of course.

Trends and projections of motor vehicle purchases

The purchases of motor vehicles fell appreciably in the depression years and again in 1938 (Figure 2). In the immediate postwar years, farmers spent more than twice as much for motor vehicles as in 1940. The demand quantity began a downward trend in the postwar years that seems to be continuing to the present time. In some recent years, annual investment has been below the 1941 level.

Equation 24-0, selected to predict the demand quantity, indicates a recent reversal of the downward postwar trend. Recent predictions by the equation are somewhat inaccurate, and the extrapolated quantity for 1960 overestimates demand by a sizeable amount. The prediction error is somewhat larger than could be expected from normal sampling variation, and may be caused by failure to specify currently significant variables in the demand function.

Assuming 1955-59 average prices and net farm income for 1965, the demand quantity is projected to be 10 percent above predicted 1960 levels by 1965. There has been a tendency for

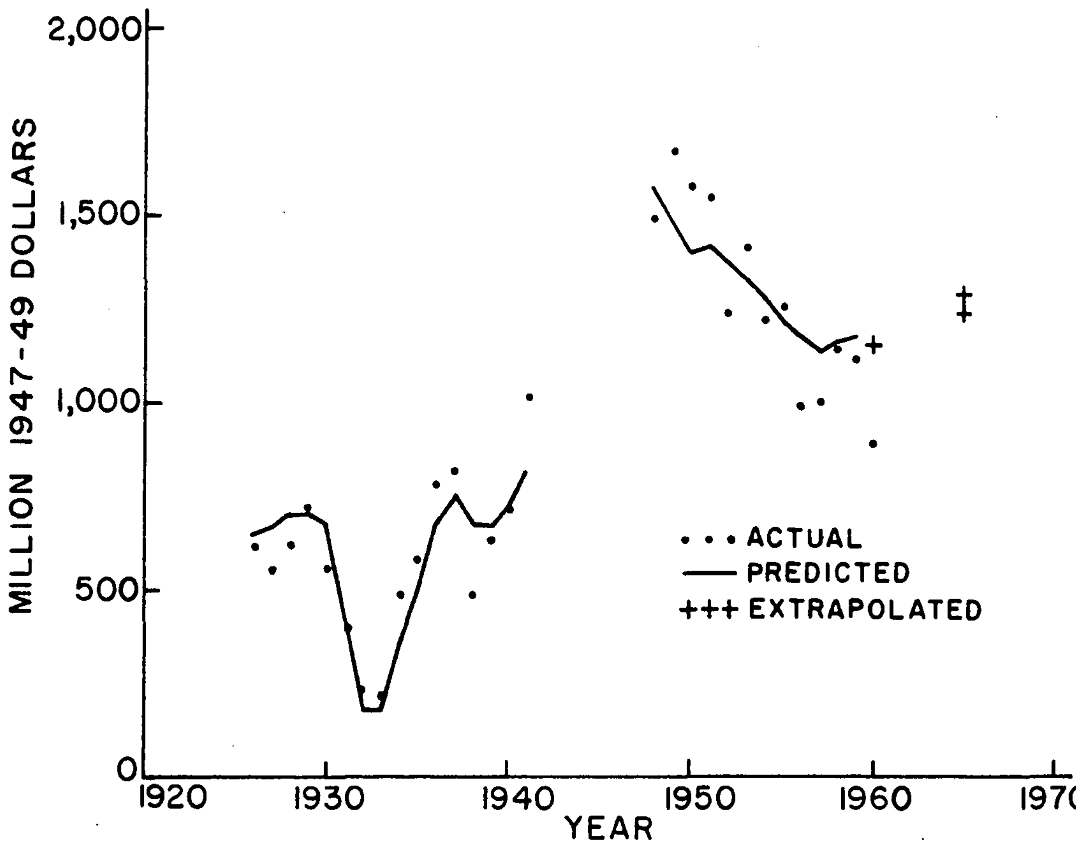

Figure 2. Trends in purchases of motor vehicles Q_{MV} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 24-0

machinery prices to increase relative to prices received in recent years. If the ratio P_M/P_R is 10 percent above the 1955-59 average in 1965 and net income remains at the 1955-59 average, then the projected demand quantity is eight percent above the predicted 1960 quantity. Hence, the equation projects a reversal of the postwar downward trend in motor vehicle purchases, and indicates that demand in 1965 will be somewhat greater than in 1960. It seems likely that relative motor vehicle prices will be higher in 1965, thus the lower projected increase of eight percent by 1965 is more reasonable.

The projections depend heavily on the underlying price and net income assumptions. One may wish to consider additional assumptions about these variables and observe the influence on the projected estimates of motor vehicle purchases. No estimate is made of the statistical standard error of prediction for 1965, but it is expected to be large for extrapolations several years in advance.

Demand for Farm Machinery and Equipment Estimated by Least Squares

Machinery and equipment includes all farm machinery other than motor vehicles. Items ranging from milking machines to combines are included in the category. The specification of the demand function for machinery and equipment is similar to the specification of demand for motor vehicles.

The variables

Variables peculiar to the demand specification for machinery and equipment are defined as follows.

Q_{MEt} The dependent variable is a weighted two-price aggregate of farm machinery and equipment purchases during the current calendar year for productive purposes (4). The variable includes planting, harvesting and tillage machines, farm wagons, sprayers, gas and electric engines, dairy machines and haying equipment, and is expressed in millions of 1947-49 dollars. Motor vehicles are excluded.

$(P_{ME}/P_R)_t$ The current year index of the ratio of prices paid by farmers for machinery and equipment to prices received by farmers for crops and livestock (120).

$(P_{ME}/P_{HL})_t$ The current year index of the ratio of machinery and equipment prices to the composite farm wage rate (120).

The price indices are adjusted to make the 1947-49 average equal 100. All variables are annual data for the U.S. from 1926 to 1959, omitting 1942 to 1947. Other variables specified in the demand function such as stock of productive assets S_p, the equity ratio E, net farm income Y_F, government programs G, and time T are defined in the section on all farm machinery.

<u>The estimated demand equations</u>

The significance of the coefficients and other properties of the estimated demand equations for machinery and equipment presented in Table 4 are similar to the estimates in Tables 1 and 3. There is little need again to discuss the common properties. Some characteristics of interest in Table 4 are the greater R^2's than in Table 3, and the significance of the adjustment coefficients in equations 36 and 37. The equations indicate that a large portion, about 70 percent, of the adjustment to the equilibrium or desired level of machinery and equipment purchases is made in the short run. That is, Table 4 supports the conclusions from Table 1 and Table 3: If farmers are subjectively certain that prices and financial circumstances are favorable, then they are not severely restrained from making a short run adjustment to desired annual investment by institutional or technological barriers. The adjustment to the desired level of stock may require considerable time despite the rapid adjustment of annual purchases, however.

The three explanatory variables in equation 32-0 and 35-0 explain 97 percent of the annual variation in the annual volume of machinery purchases. The adjusted coefficient of determination $R^2 = 0.97$ in these equations is higher than the R^2 in the adjustment equations 36-0 and 37-0 despite the significant coefficients of lagged quantity in the latter equa-

Table 4. Demand (annual gross investment) functions for farm machinery an
data from 1926 to 1959, omitting 1942 to 1947; coefficients, sta

Equation, transformation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_{ME}/P_R t	P_{ME}/P_R t-1	P_{ME}/P_{HL} t	P_{ME}/P t-1
28-0	B	0.97 0.96	1.25	692.73	-3.32 (0.68)	0.14 (1.10)		-0.77 (0.97
29-0	AB	0.97 0.97	1.25	191.64	-3.11 (0.54)			
29-L	AB	0.96 0.96	1.90	0.91	-1.81 (0.25)			
30-0	B	0.94 0.93	1.29	173.26		-3.22 (1.02)		0.38 (0.71
31-0	B	0.97 0.97	1.23	433.73	-2.94 (0.63)		-0.58 (0.49)	
32-0	B	0.97 0.97	1.18	346.25	-3.45 (0.47)			
33-0	A	0.95 0.95	1.10	-121.88	-3.19 (0.68)			
33-L	A	0.95 0.94	0.90	1.87	-1.56 (0.28)			
34-0	A	0.96 0.96	1.02	-161.47	-2.98 (0.61)			
34-L	A	0.95 0.94	0.83	1.75	-1.55 (0.29)			

[a]Sources and composition of the dependent variable Q_{ME} and of the indi

[b]Equations estimated in original observations are designated by 0; in
values in the L equations. Also Y_{DFt-1} in the logarithm equations is the l
and adjustment models are presented in Chapter 7.

[c]The Durbin-Watson autocorrelation statistic d'.

ss investment) functions for farm machinery and equipment other than motor vehicles Q_{ME} estim
1959, omitting 1942 to 1947; coefficients, standard errors (in parenthesis) and related stati

Constant	P_{ME}/P_R t	P_{ME}/P_R t-1	P_{ME}/P_{HL} t	P_{ME}/P_{HL} t-1	S_p t	E t-1	Y_F t	Y_F t-1	Y_F t-2
692.73	-3.32	0.14		-0.77	-3.67	38.82			
	(0.68)	(1.10)		(0.97)	(7.57)	(15.10)			
191.64	-3.11					47.59		0.014	
	(0.54)					(12.16)		(0.011)	
0.91	-1.81					-0.69		1.28	
	(0.25)					(0.22)		(0.24)	
173.26		-3.22		0.38		55.82			
		(1.02)		(0.71)		(14.97)			
433.73	-2.94		-0.58			56.12			
	(0.63)		(0.49)			(8.94)			
346.25	-3.45					58.17			
	(0.47)					(8.84)			
-121.88	-3.19							0.044	
	(0.68)							(0.010)	
1.87	-1.56							0.89	
	(0.28)							(0.25)	
-161.47	-2.98							0.027	0.0224
	(0.61)							(0.011)	(0.0080)
1.75	-1.55							0.86	0.060
	(0.29)							(0.28)	(0.212)

n of the dependent variable Q_{ME} and of the indicated independent variables are discussed in th

original observations are designated by O; in logarithms of original observations by L. The
Also Y_{DFt-1} in the logarithm equations is the logarithm of the simple declining arithmetic ave
esented in Chapter 7.

correlation statistic d'.

nd equipment other than motor vehicles Q_{ME} estimated by least squares with annual
andard errors (in parenthesis) and related statistics are included[a]

$/P_{HL}$ t-1	S_p t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_{ME} t-1
7	-3.67	38.82					2.95	14.61	
7)	(7.57)	(15.10)					(2.86)	(5.92)	
		47.59		0.014				10.96	
		(12.16)		(0.011)				(2.46)	
		-0.69		1.28				0.0254	
		(0.22)		(0.24)				(0.0038)	
8		55.82						12.18	
1)		(14.97)						(4.34)	
		56.12						9.04	
		(8.94)						(2.68)	
		58.17						10.37	
		(8.84)						(2.45)	
				0.044				18.18	
				(0.010)				(2.07)	
				0.89				0.0151	
				(0.25)				(0.0022)	
				0.027	0.0224			16.91	
				(0.011)	(0.0080)			(1.88)	
				0.86	0.060			0.0149	
				(0.28)	(0.212)			(0.0024)	

dicated independent variables are discussed in the text.

n logarithms of original observations by L. The time variable T is in original
logarithm of the simple declining arithmetic average net farm income. Expectation

Table 4. (Continued)

Equation, transformation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_{ME}/P_R t	P_{ME}/P_R t-1	P_{ME}/P_{HL} t
35-O	C	0.97 0.97	1.04	-147.18	-3.04 (0.52)		
35-L	C	0.93 0.93	0.58	3.15	-1.81 (0.29)		
36-O	BF	0.97 0.96	1.35	305.48	-3.01 (0.48)		
37-O	F	0.97 0.96	1.37	79.16	-2.69 (0.57)		
37-L	F	0.96	0.65	3.26	-1.52 (0.25)		
38-L	H	0.98 0.97	1.14	-2.20	-1.46 (0.37)	1.06 (0.37)	

P_{ME}/P_R t-1	P_{ME}/P_{HL} t	P_{ME}/P_{HL} t-1	S_p t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t
								0.0504	
								(0.0077)	
								0.69	
								(0.28)	
				36.91					
				(12.50)					
						0.019			
						(0.011)			
						0.36			
						(0.31)			
1.06					0.47	0.60			
(0.37)					(0.25)	(0.27)			

p	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_{ME} t-1
					0.0504		16.43	
					(0.0077)		(1.71)	
					0.69		0.0161	
					(0.28)		(0.0026)	
	36.91						9.13	0.26
	(12.50)						(2.33)	(0.11)
			0.019				12.04	0.39
			(0.011)				(2.38)	(0.11)
			0.36				0.0127	0.28
			(0.31)				(0.0023)	(0.12)
		0.47	0.60				0.0038	0.51
		(0.25)	(0.27)				(0.0028)	(0.11)

tions. The coefficients of the variables in equations 32-0 and 35-0 have the anticipated signs and each is highly significant. These expectation equations provide useful and meaningful expressions of machinery demand. A note of caution is suggested by the Durbin-Watson statistic which indicates the possibility of autocorrelation in the residuals and consequent loss of statistical efficiency.

The high R^2 in equation 38, estimated linear in logarithms only, indicates certain positivistic advantages for model H. The model predicts well but the signs and magnitudes of some coefficients (e.g. the coefficient of $(P_{ME}/P_R)_{t-1}$) are suspect. High correlations between explanatory variables negates the usefulness of model H for making inferences about structural parameters.

Price and income elasticities of demand for farm machinery and equipment

Equations 34-0 and 35-0 indicate that the elasticity of demand for farm machinery other than motor vehicles with respect to $(P_{ME}/P_R)_t$ is -0.75. The total elasticity with respect to income computed from the same equations approximately is 0.86. Assuming that a one percent rise in $(P_R/P_P)_t$ increases net income by two percent (cf. Appendix B), the long run elasticity of Q_{ME} with respect to P_P is -1.50, with respect to P_R is 0.75 plus 1.50, or 2.25. Similar computations from equation 34-L indicate the elasticity of Q_{ME} with respect to the price variable P_{ME} is -1.55, P_P is -(2.0)(0.86) = -1.72, and P_R (long run) is 1.55 plus 1.72, or 3.3. Assuming the average of these estimates is relevant, a sustained one percent increase in prices received by farmers is expected to increase machinery purchases slightly more than one percent in the short run, and nearly three percent in the long run. The elasticities from equations estimated in original observations are calculated at the means of the variables.

The elasticities of machinery and equipment stock may be approximated from the above elasticities. Since annual purchases are only one-fifth of machinery and equipment stock on the average, the short run elasticity of stock with respect to P_{ME}/P_R is (0.2)(-0.75) = -0.15 based on equations 34-0 and 35-0. Since the adjustment rate and ratio between annual purchases and stock are assumed to be nearly equal for machinery and equipment, the long run elasticity for stock and annual investment with respect to P_R are the same magnitude, or 2.25. But the "long run" for Q_{ME} is three or four years, whereas only about 90 percent of the adjustment to the "long run" of stock is made in 10 years (assuming the adjustment coefficient is 0.2). The adjustment coefficient 0.2 is based on the equations in Table 1. The long run elasticity of stock is particularly sensitive to the magnitude of the adjustment coefficient. It is difficult to obtain an accurate estimate of the coefficient because the influence of other variables correlated with stock is confounded in the coefficient of the lagged stock variable. The reader may wish to consider the magnitude of the elasticity under alternative assumptions about the value of the adjustment coefficient.

<u>Trends and projections of farm machinery and equipment purchases</u>

The trend in machinery and equipment purchases, shown in Figure 3, is similar to the trend in motor vehicle purchases. The quantities appear to follow a somewhat more uniform trend in Figure 3, however, and there appears to be stronger signs of a reversal of the postwar decline in purchases. Equation 35-0 estimates the actual quantities reasonably well, and the error in predicting the 1960 quantity is small. The equation appears to be a useful predictive device.

Assuming prices and net farm income are at 1955-59 values in 1965 and that equation 35-0 is the correct demand structure, purchases of machinery and equipment are projected to be 18 percent above predicted 1960 levels by 1965. If the price of machinery and equipment is 10 percent higher in 1965, but net income is at the 1955-59 level, the demand quantity is projected to increase 12 percent over the 1960 predicted value by 1965.

The assumption that net income will remain at the 1955-59 level may be overly optimistic. It essentially is based on the assumption that demand for farm products will expand

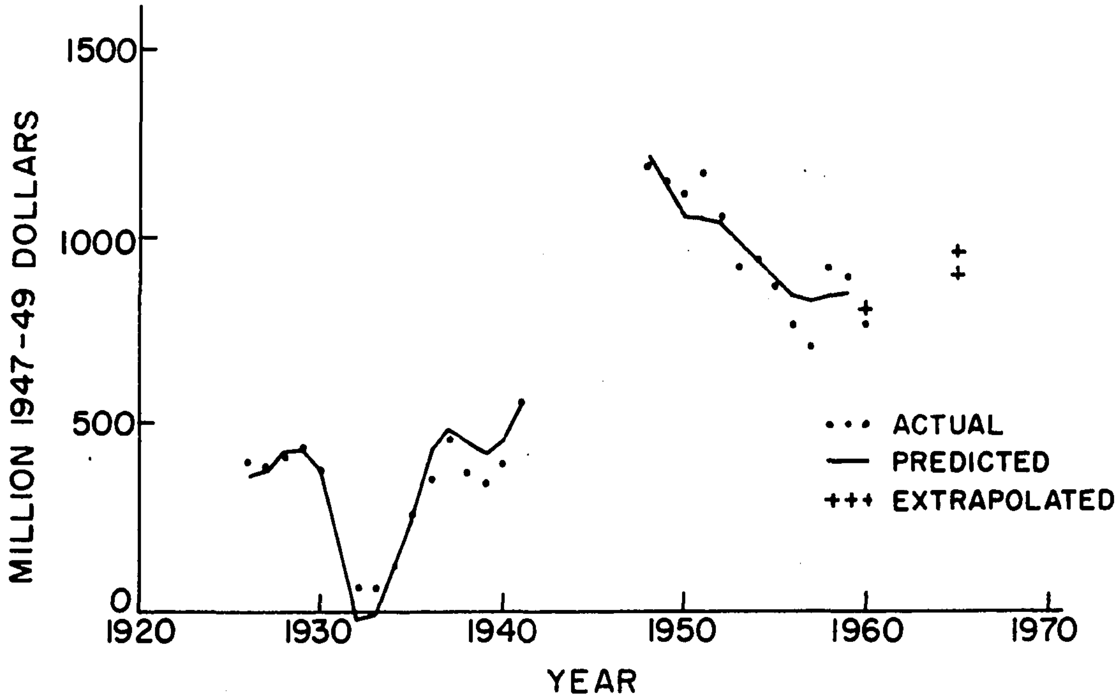

Figure 3. Trends in purchases of farm machinery other than motor vehicles Q_{ME} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 35-0

uniformly with farm output, and leave P_R nearly unchanged. Gross receipts, however, are expected to be greater because more units of output will be marketed. Furthermore, farms will become more efficient, producing more output with the same or fewer resources. These tendencies to increase income may be offset or more than offset by increased input prices and greater reliance on purchased inputs. Thus, net income is expected to remain nearly unchanged by 1965 (73, p. 18). Historically, machinery prices have displayed a tendency to increase relative to farm output price. The more conservative estimate of a 12 percent rise in machinery purchase by 1965 probably is most realistic.

Demand for Building Improvements Estimated by Least Squares

The final category of investment examined in this chapter is building improvements. The two previous categories Q_{MV} and Q_{ME} were investigated in the aggregate as Q_M and, therefore, were treated in a somewhat cursory manner. Building improvements are a quite different form of investment than those considered earlier and are discussed in more detail.

While the virgin soil resources remained stable or declined because of cropping attrition and requirements for non-agricultural uses, the physical volume of total real estate increased 10 to 20 percent from 1926 to 1959 (4, 123). The increase largely is due to annual investment in building improvements, including fences, windmills and wells. In this study, the demand quantity (annual gross investment) of building materials is specified as a function of prices, beginning year stock of assets, equity, net farm income, farm size, the interest rate and slowly changing influences represented by the time variable. Several of the variables are defined in the earlier section on all farm machinery.

The variables

The variables not defined earlier but included in the least squares equations are:

Q_{BIt} The dependent variable is the national aggregate of expenditures on building improvements, including fences, windmills, wells and dwellings not occupied by the farm operators, deflated by prices paid by farmers for building materials (120, 121). The variable is in millions of 1947-49 dollars.

$(P_B/P_R)_t$ The current year index of the ratio of the price of building materials to prices received by farmers for crops and livestock (120).

$(P_B/P_P)_{t-1}$ The past year index of the ratio of the price of building materials to prices paid by farmers for items used in production, including interest, taxes and wage rates (120).

S_{Bt} The stock of farm buildings, excluding operators' dwellings on farms at the beginning of the current year. The variable is constructed from benchmark (census year) estimates by Tostlebe, and interpolating between these benchmarks from USDA (114, 121) data on building expenditures and depreciation. The variable is in millions of 1947-49 dollars.

All price indices are expressed as a percentage of the 1947 to 1949 average. All variables are annual data for the U.S. from 1926 to 1959, omitting 1942 to 1945. The assumption is that the supply of building materials was comparatively less restricted than the supply of machinery in 1946 and 1947. The equations for building improvements do not display large prediction errors for these years and it does not appear to be unrealistic to include the two observations.

The estimated demand equations

The seven independent variables in equation 39, Table 5, explain 98 percent of the annual variation about the mean of Q_{BIt}. Coefficients of only three of the variables -- $(P_B/P_R)_t$, S_{pt} and E_{t-1} -- are significant, however. The pattern is similar to machinery demand. That is, the past year prices and G are non-significant. One notable difference is that the coefficient of S_p rather than T is signifi-

Table 5. Demand (annual gross investment) functions for building im
omitting 1942 to 1945; coefficients, standard errors (in p

Equation, transformation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_B/P_R t	P_B/P_R t-1	P_B/P_P t-1	
39-0	B	0.98	1.77	-832.90	-3.59	0.64	-2.58	18
		0.97			(0.83)	(1.01)	(3.07)	(3
40-0	AB	0.98	1.48	-895.83	-3.58			18
		0.97			(0.77)			(2
40-L	AB	0.94	1.49	-8.12	-2.60			6
		0.92			(0.55)			(1
41-0	B	0.96	1.18	-923.30		-2.52	0.57	15
		0.95				(0.91)	(3.56)	(4
42-0	B	0.98	1.58	-990.70	-3.27			19
		0.97			(0.55)			(2
43-0	A	0.94	1.77	-1631.95	-2.44			21
		0.93			(1.14)			(4
43-L	A	0.94	1.38	-7.68	-2.58			6.
		0.93			(0.54)			(1.
44-0	C	0.97	1.45	-1659.44	-2.18			21.
		0.96			(0.77)			(3.
44-L	C	0.94	1.11	-7.99	-2.54			6.
		0.93			(0.44)			(1.
45-0	BF	0.95	1.29	76.71	-2.35			
		0.95			(0.75)			

[a]Sources and composition of the dependent variable Q_{BI} and of the

[b]Equations estimated in original observations are designated by O in the L equations. Also Y_{DFt-1} in the L equations is the logarithm o adjustment models are presented in Chapter 7.

[c]The Durbin-Watson autocorrelation statistic d'.

functions for building improvements Q_{BI} estimated by least squares with annual dat
its, standard errors (in parenthesis) and related statistics are included[a]

/P_R t	P_B/P_R t-1	P_B/P_P t-1	S_P t	E t-1	Y_F t-1	Y_{DF} t-1	G t	T
.59	0.64	-2.58	18.53	49.39			0.83	-2.15
.83)	(1.01)	(3.07)	(3.17)	(10.32)			(2.35)	(4.91)
.58			18.69	59.22	-0.0058			-5.05
.77)			(2.04)	(10.03)	(0.0100)			(3.00)
.60			6.81	-0.11	0.66			0.0039
.55)			(1.41)	(0.32)	(0.46)			(0.0074)
	-2.52	0.57	15.86	56.79				-4.02
	(0.91)	(3.56)	(4.01)	(10.68)				(6.33)
.27			19.04	54.65				-5.27
.55)			(2.84)	(6.15)				(2.94)
.44			21.76		0.0406			-0.47
.14)			(4.44)		(0.0096)			(4.45)
.58			6.74		0.57			0.0026
.54)			(1.37)		(0.38)			(0.0063)
18			21.68			0.0482		-2.56
77)			(3.34)			(0.0068)		(3.30)
54			6.60			0.70		0.0019
44)			(1.32)			(0.34)		(0.0059)
35				31.81				6.91
75)				(10.99)				(2.81)

nt variable Q_{BI} and of the indicated independent variables are discussed in the tex

ations are designated by O; in logarithms by L. The time variable T is in original
iations is the logarithm of the simple declining average net farm income. Expectat
.

istic d'.

Q_{BI} estimated by least squares with annual data from 1926 to 1959,
) and related statistics are included[a]

: -1	Y_F t-1	Y_{DF} t-1	G t	T	Q_{BI} t-1	S_B t
39			0.83	-2.15		
32)			(2.35)	(4.91)		
22	-0.0058			-5.05		
03)	(0.0100)			(3.00)		
11	0.66			0.0039		
32)	(0.46)			(0.0074)		
79				-4.02		
68)				(6.33)		
65				-5.27		
15)				(2.94)		
	0.0406			-0.47		
	(0.0096)			(4.45)		
	0.57			0.0026		
	(0.38)			(0.0063)		
		0.0482		-2.56		
		(0.0068)		(3.30)		
		0.70		0.0019		
		(0.34)		(0.0059)		
1				6.91	0.39	
9)				(2.81)	(0.11)	

independent variables are discussed in the text.

ithms by L. The time variable T is in original values
le declining average net farm income. Expectation and

Table 5. (Continued)

Equation, transformation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_B/P_R t	P_B/P_R t-1	P_B/P_P t-1
46-O	F	0.94 0.93	1.53	-45.16	-2.30 (1.14)		
46-L	F	0.96 0.96	1.52	8.22	-2.47 (0.43)		
47-O	BG	0.97 0.97	1.42	-289.21	-3.24 (0.58)		
48-O	G	0.93 0.92	1.45	-828.20	-2.42 (1.25)		
48-L	G	0.94 0.93	1.41	-6.40	-2.51 (0.54)		

P_B/P_R t-1	P_B/P_P t-1	S_p t	E t-1	Y_F t-1	Y_{DF} t-1	G t	T	
				0.012			9.70	C
				(0.011)			(2.95)	(C
				-0.75			0.0204	C
				(0.36)			(0.0033)	(C
			59.40				2.16	
			(6.56)				(2.40)	
				0.043			9.60	
				(0.011)			(3.39)	
				0.67			0.0165	
				(0.38)			(0.0045)	

Y_F t-1	Y_{DF} t-1	G t	T	Q_{BI} t-1	S_B t
0.012			9.70	0.54	
(0.011)			(2.95)	(0.11)	
-0.75			0.0204	0.639	
(0.36)			(0.0033)	(0.088)	
			2.16		0.060
			(2.40)		(0.010)
0.043			9.60		0.063
(0.011)			(3.39)		(0.016)
0.67			0.0165		2.66
(0.38)			(0.0045)		(0.55)

cant, perhaps because the productive assets variable absorbs the time trend.

Addition of income Y_F to the equation does not improve the results according to equation 40. E_{t-1} reflects the influence of income and is the stronger of the two variables. Equation 40-L does not indicate the influence of E, and later equations including the variable are estimated only in original observations.

That the current and past values of P_B/P_R compete in explaining the demand quantity is evidenced by equation 41. The significance and magnitude of the coefficient falls for the past value of price in equation 41, indicating that current as well as past price is important. Although equation 41 is useful for predicting quantities when current price is unavailable, some bias may result. It seems wise to include only current price and to interpret the coefficient as the influence of both current and past prices. Equation 42 is equation 39 with the price and institutional variables having insignificant coefficients omitted. Later the equation is the basis for estimates of demand shifts and elasticities.

Equations 43 and 44 indicate the influence of past income on annual investment in building improvements. The coefficient of income increases from 0.041 to 0.048 as additional lagged values of income are included in equations 43-0 and 44-0, respectively. The small size of the increment indicates that additional lags might add little to the coefficient of income.

Some evidence for the adjustment model to represent annual gross building investment is provided by equations 45 and 46. The results indicate that if expectations are specified as in equation 45, the adjustment is very rapid -- about 60 percent in the short run. This implies that the adjustment of annual purchases to desired levels occurs quickly, but does not indicate the speed of adjustment to the desired level of stock. Inclusion of lagged building stock in investment equation 47 improves the fit over equation 45 and allows approximate determination of the adjustment coefficient. The coefficient of lagged stock is positive and highly significant. Because it is the depreciation coefficient h less the adjustment coefficient g, it indicates h exceeds g by 0.06. The exact depreciation rate is unknown but probably is considerably below the machinery depreciation rate. If the depreciation rate is 0.10, the adjustment rate is 0.10 - 0.6 = 0.04, a slow rate of adjustment indeed. Some difficulty in estimating the coefficient is evidenced by equation 48-L. The coefficient of lagged stock is large, significant and unrealistic. The complication may arise because: (a) expectations are not adequately considered in the equation, (b) other variables not included in the equation but correlated with S_B exert a strong positive influence on Q_{BI}, and

(c) the stock variable is crudely formulated and subject to error. The result is that no great confidence may be placed in the estimate of the adjustment coefficient. Since the depreciation rate is low, a large number of years may pass before the equilibrium stock is reached, i.e. where $Q_{BI} = h\, S_B$.

It is notable that the R^2's are somewhat lower for the adjustment equations 45 to 48 than for the previous conventional equations 42-0 and 44-0. Comparing equations estimated in original values and in logarithms, the former generally explain more variation in the dependent variable, display more meaningful coefficients based on economic theory, and indicate a lower degree of autocorrelation in the residuals. In subsequent analysis, we rely heavily on the equations in original values for inferences about the nature of investment in building improvements.

Two additional variables, cropland acres per farm and the short term interest rate, were included in an equation with P_B/P_R, S_p, E and T. The coefficients of both added variables statistically were insignificant, and the equation is not included in Table 5.

Price and income elasticities of demand for building improvements

According to equation 42, the short run elasticity of Q_{BI} with respect to $(P_B/P_R)_t$ is -0.88. A sustained one percent increase in net income raises E 1.57 percent according to equation 15. Using this relationship, the elasticity of Q_{BI} with respect to net income is 1.30. If a one percent increase in P_R/P_P increases net income two percent (cf. Appendix B), the long run elasticity of demand for Q_{BI} with respect to P_R is 0.88 (from $(P_M/P_R)_t$) plus 2.60 (from E), or 3.48. The elasticity is computed at the means of the variables found in equation 42.

The result indicates that investment in real estate improvements is more responsive than investment in machinery to price changes. Average annual investment in building improvements is a small proportion of building stock because depreciation (replacement requirements) is low. A large percentage change in annual investment is required if only a small increase in stock is desired. This explains the high elasticity of annual investment -- particularly of annual investment in building improvements. Three or four years after a sustained one percent rise in prices received by farmers, annual investment will be more than three percent above the initial investment according to the above results. The depreciation rate and pattern of resource use is such that farmers may easily postpone investment in real estate improvements in unfavorable years without seriously reducing production. In favorable years, the opportunity and need to expand investment in building improvements are great, partially because an improved financial situation permits purchase of building improvements (which are a major nondivisible expense in many instances) and also because a backlog of improvements may have developed during depressed periods.

Since annual investment tends to be a small proportion of the stock of buildings on farms, the elasticity with respect to S_B is much below the above estimates. The elasticity of S_B with respect to $(P_B/P_R)_t$ from equation 47 is only -0.06. The intermediate run elasticity (after Q_{BI} has reached the desired level) of S_B with respect to P_R is 0.14, computed from the same equation. In spite of the elastic demand for Q_{BI}, a sustained one percent increase in P_R would increase building stocks only 0.14 percent in about four years according to the above estimate. If the adjustment coefficient is 0.04, the long run elasticity of stock with respect to P_R is 3.5. The "long run" is very far away; more than 50 years are required to make 90 percent of the desired adjustment! The data are tenuous and subject to large errors. Hence, the above results should be considered hypothesis for further testing rather than as conclusive and precise estimates.

<u>Trends and projections of building improvement purchases</u>

Figure 4 indicates that investment in building improvements fell appreciably in the depression years, then recovered

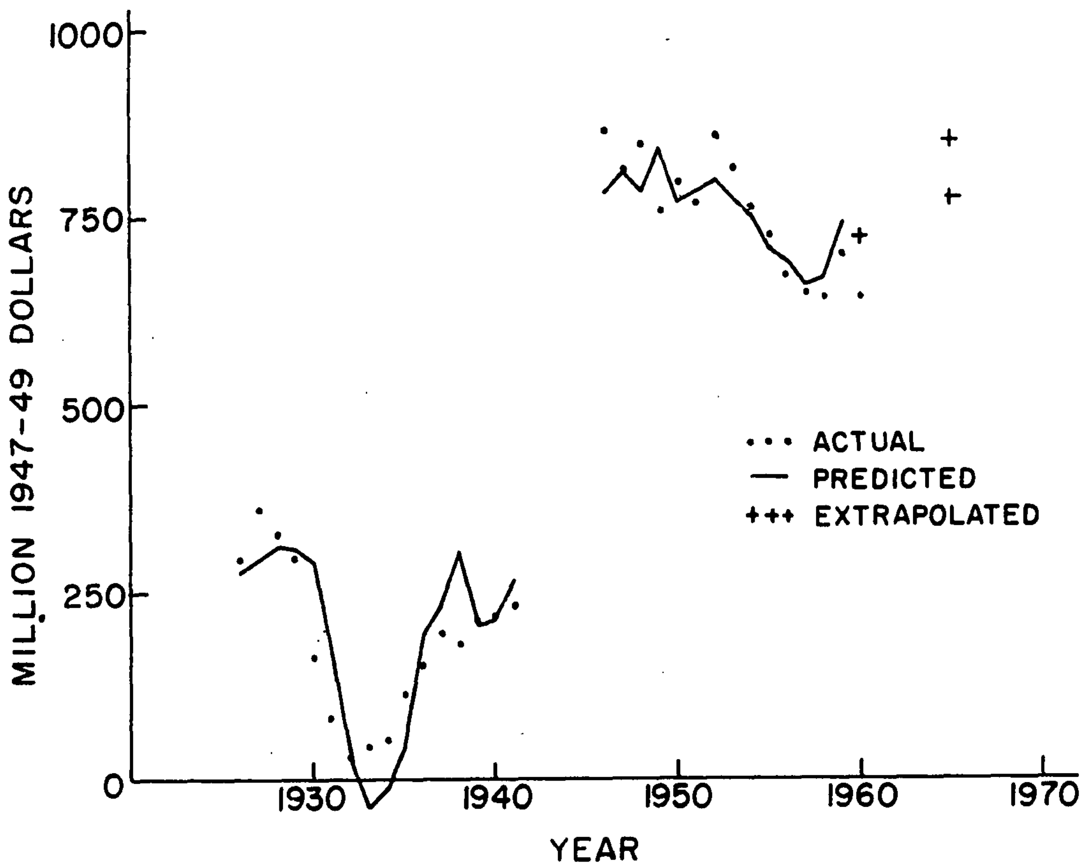

Figure 4. Trends in purchases of building improvements Q_{BI} from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 44-0

in the late 1930's but not to the immediate pre-depression level. Annual investment in the postwar period was on a totally higher plane than during the postwar period. As the backlog of demand created by depreciated stocks, latent technology, rationing of material and improved farm financial situation was filled, the demand quantity declined in the mid 1950's. There is some evidence that the downward trend of recent years is slowing.

Actual observations are predicted by equation 44-0 for the 33-year period. The fit generally is good, but some large errors are apparent. The extrapolated estimate for 1960 exceeds the actual observation by several million dollars. The error appears larger than might be ascribed to normal sampling variation. The result partially may be caused by failure to include recent structural changes in the model. The "actual" observation for 1960 is preliminary, and later revisions sometimes reduce the degree of error.

Gross annual investment Q_{BI} is projected to 1965 from equation 44-0 under various assumptions concerning the level of farm income and prices. The higher projection probably is overly optimistic and indicates that Q_{BI} will be 13 percent above the predicted 1960 level by 1965. The projection is based on the assumption that prices and farm income will be at 1955-59 levels in 1965. S_D is estimated from investment equation 28, Chapter 9, to be 114.4 billion 1947-49 dollars on January 1, 1965, assuming output will increase eight percent by 1965 (73).

The lower projected estimate of gross investment in building improvements appears to be more realistic and indicates Q_{BI} will be only seven percent above the 1960 level by 1965. It is based on the assumption that the real price of building materials P_B/P_R will be 10 percent greater in 1965 than the 1955-59 average. It is also based on the assumption that S_p will be 112.4 billion 1947-49 dollars on January 1, 1965 (73).

Other quite different projections could be obtained under differing assumptions about prices, income, output, etc. Time limitations prevent an extensive exploration of many alternative assumptions. The reader may wish to explore these, using the coefficients in equation 44-0 or others in Table 5. Alternative assumptions about the income level in 1965 might be particularly interesting.

Changes in Annual Investment in Machinery and Building Improvements

Table 6 indicates the total and annual increases in gross investment in farm machinery and building improvements from 1926 to 1959. Three sources of the increased annual investment Q_i and the variables representing each are: (a) price $(P_i/P_R)_t$, (b) earnings and equity E, and (c) structure T (S_p and T for Q_{BI}). Other changes may be associated with

Table 6. Estimated percentage changes in annual purchases (gross investment) in farm machinery and building improvements from 1926 to 1959 attributed to prices, equity and demand structure based on selected equations[a]

Input and equation	Percentage change in gross annual investment attributed to:									
	Price		Earnings and equity		Structure		Total by regression		Actual change	
	Full period	Annual average[b]	Full period	Annual average[b]	Full period	Annual average[b]	Full period	Annual average[b]	Full period	Annual average[b]
Q_M 5-0	-53.55	-2.35	59.49	1.42	80.75	1.81	86.69	1.91	108.69	2.25
Q_{MV} 21-0	-52.88	-2.31	52.16	1.28	73.53	1.68	72.81	1.67	90.18	1.97
Q_{ME} 32-0	-49.83	-2.11	77.00	1.75	89.35	1.95	116.52	2.37	140.99	2.70
Q_{BI} 42-0	-54.27	-2.40	99.35	2.11	109.74[c]	2.27[c]	154.82	2.88	140.22	2.69

[a]The three sources of increases in the demand quantities are estimated from the three explanatory variables in the demand equation, i.e. price $(P_1/P_R)_t$, earnings and equity E_{t-1} and structure T. For example, the demand equation for all machinery is of the form:

(a) $Q_M = a + b\,E_{t-1} + c\,P_M/P_{Rt} + d\,T + u_t$.

The total percentage increase predicted by regression from 1926 to 1959 is found from the predicted values Q'_M of machinery purchases:

(b) Total percentage increase by regression $= 100 \left[\dfrac{Q'_M\ (1959)}{Q'_M\ (1926)} - 1\right]$

(c) Total percentage shift attributed to price $(P_1/P_R)_t$ =

$$\frac{100\ c\ [P_M/P_R\ (1959) - P_M/P_R\ (1926)]}{Q'_M\ (1926)}.$$

[b]The compound average annual change.

[c]For building improvements, "structure" includes S_p and T.

errors in prediction, indicated by the difference between the total percentage change by regression and the actual percentage change.

Shifts in machinery demand

Since shifts in demand for all machinery Q_M, motor vehicles Q_{MV} and machinery other than motor vehicles Q_{ME} are similar, only the results for Q_M and Q_{BI} are discussed in detail. Consider first the demand for all farm machinery. The actual changes which, in fact, have occurred in demand for machinery depend on the parameters of the demand functions as well as on the relative shifts in prices, income and other relevant variables. The standard partial regression coefficients indicate the relative impact that variables can have on the demand quantity Q_M. These respective coefficients for the price, farm income and time variables computed from equation 8-0 are -1.4, 1.5 and 2.2. These coefficients indicate that the influences represented by the time variable potentially are important in determining the demand quantity. The magnitudes of the other influences are sizeable also, and if historic trends in the price or income variables are large, either one could be responsible for a greater portion of the change in Q_M than the time variable.

According to Table 6, actual purchases (constant 1947-49 dollars) of all farm machinery increased 109 percent since

1926, or at an average compound rate of 2.25 percent per year. Equation 5-0 provides a basis for investigating the sources of the increase. Real machinery price $(P_M/P_R)_t$ was over 60 percent greater in 1959 than in 1926. If other variables had been at 1926 values but P_M/P_R had been at the 1959 value in 1926, the demand quantity would have been 54 percent below the actual 1926 purchases according to equation 5-0. The more than 100 percent increase in demand for machinery during the 33-year period can hardly be attributed to the falling relative price of machinery.

Equation 5-0 indicates that machinery purchases would have been 60 percent greater in 1926 if farmers would have experienced the financial or equity position present in 1959, ceteris paribus. More efficient methods of production, substitution of cheap operating inputs for farm labor and horsepower, improved management and inflation permitted a slight increase in net farm income and a considerable improvement in the equity of farmers from 1926 to 1959 despite the rise in the ratio P_M/P_R. An "accelerator" influence may be evident, since adoption of machinery in early years partially was responsible for the increased efficiency and improved financial position of farmers, permitting greater machinery purchases in later years.

Table 6 indicates that the major source of the increased machinery demand has been structural changes represented by the time variable. The two "economic" categories (a) price and (b) earnings or equity, nearly offset one another, leaving "structure" to explain almost the entire shift in machinery demand since 1926. Most notable of the structural changes embodied in the time variable is the continuous improvement in the quality and adaptability of machinery. Concurrent with these improvements is the increased awareness by farmers of the returns and convenience from using improved machinery. Of course, it is well to remember that the structural and financial categories are not entirely independent.

The non-farm sector has performed an important role in farm mechanization despite the ignoring of machinery supply in Table 6. If the supply of farm machinery were not highly elastic and if a small increase in farm demand would have brought sharp machinery price increases, farm mechanization, undoubtedly, would have progressed less rapidly. The fact that manufacturers have made farm machines available in quantities and of the quality desired by farmers has been an important element explaining the rapid growth of farm machinery stock. In turn, the rising stock of farm machinery and substitution of machinery for farm produced power has been a significant element in the rising farm labor efficiency.

Several direct and indirect sources of the annual 1.8 percent increase in Q_M attributed to structure can be cited. The direct influences reflected in the time coefficient are gradual increases in the quality, adaptability and convenience of machinery, coupled with growing knowledge by farmers of the benefits to be gained from mechanization. But more fundamental and indirect sources of the structural shift in demand may be found. Perhaps the most basic indirect source of the structural increase in machinery demand is the growth of the American educational plant. Without the large investment in education, it is unlikely that engineering and other talents of human resources would have been able to develop rapidly the steel, coal and automobile industries so vital to the growth of the farm machinery industry. Education also was important in providing a farm management base and broad perspective in farmers necessary for the adoption and efficient utilization of farm machinery. Human ingenuity was a basic element in the invention of the internal combustion engine, steelmaking processes, etc. Less basic than education but perhaps the most important "intermediate" factor responsible for the development of the farm machinery industry and farm mechanization, was the growth of the automobile industry in this country. Without the know-how and industrial climate created by the auto industry, it is doubtful that farm mechanization would have occurred so quickly.

Thus, the development of America's agriculture is an interdependent accomplishment. The basic ingredients are the natural resources, educational attainment and technological know-how for building farm machines and the desire and ability to use them profitably on farms. On this foundation, the total economy grows as the machines are made available to farmers, adding to financial surpluses for purchasing more machines. Simultaneously, workers who are freed from farming, provide the basis for further expansion of industry and improved standards of living for both the farm and non-farm sectors. Although the growth of America's agricultural plant principally was financed internally from net farm income, a strong non-farm sector, undoubtedly, can be an important source of credit in times of rapid expansion of farm investment.

Shifts in building improvement demand

In 1959, annual gross investment in building improvements was 140 percent above the 1926 level. Equation 42-0 is used as a basis for estimating the sources of this increase in annual investment. Three hypothetical sources of the investment increase are: (a) prices P_B/P_R, (b) earnings and equity E, and (c) structure S_p and T. Because of the correlation between S_p and T, it is advisable to give the variables a joint interpretation. If 1959 values are given these variables, equation 42-0 indicates demand would have been 155 percent greater than in 1926, hence, some discrepancy exists between the actual and predicted changes in demand quantity.

If price P_B/P_R had been at 1959 level in 1926, other things equal, the demand quantity would have been 50 percent <u>less</u> than the actual demand in 1926 according to equation 42-0. If earnings and equity had been at the 1959 value in 1926, demand would have been 100 percent above the 1926 level, other things equal. Because other input prices fell and because efficiency increased, farmers apparently improved their financial status sufficiently to increase purchases of building improvements by a sizeable amount. The influence of both price and equity would increase demand by a net of about 50 percent. Hence, the remaining portion of the total 140 percent increase remains to be explained by structural changes. Included in structural changes are a broad range of physical and technological influences. Examples are the large building investment needed to store and house increased inventories of livestock and feed. Technological influence may not be as dramatic as for farm machinery. Nevertheless, changes in methods of storing feeds, handling dairy cattle, etc. have influenced demand for buildings. Influences tending to reduce farm numbers and replace labor with other resources also have created an impact on the investment in real estate improvements. Some of these influences reduce demand, others increase demand, but the net influence according to equation 42-0 is to shift demand to the right approximately two percent per year.

Summary of Empirical Results

The empirical analysis in Chapter 8 indicates that annual investment in machinery and buildings substantially may be explained by: (a) current own-price relative to prices received by farmers, (b) net farm income or the equity ratio and (c) gradually changing influences represented by a time or productive assets variable. The single equation provides more realistic results than the limited information demand equation, hence, is the basis for subsequent inferences.

As anticipated, demand for durable inputs is sensitive to prices and is considerably more price elastic than the demand for operating inputs. The fact that it is necessary for farmers to adjust annual investment by a large percentage to secure even a small change in desired stock accounts for the high elasticity. A surprising degree of uniformity is apparent among durable input categories in the response of annual gross investment to price changes. The magnitude of the price elasticities may be illustrated by a simple example. Assume that annual investment and prices initially are at an index of 100. Assume further that farm product price increases to 101 in year t and remains at that level for many years. After one or two years, annual investment may be expected to increase from 100 to 101. After three or four years, the index of annual investment approximately is 102 or 103 for any one of the categories of investment according to the results of Chapter 8. If the price of output is at 100 but the investment item price decreases to 99, the index of investment again will increase to 101 in a year or two, but does not increase any more, even after a number of years.

There is less uniformity in the influence of prices on <u>stocks</u> among durable inputs. If prices received by farmers increase from 100 to <u>110</u> in year t, the stock of machinery will increase from 100 to 102 in one or two years, to 105 in three or four years and to 125 in 10 or more years according to the equations in Tables 1, 3 and 4. For the same sustained increase in prices received, the stock of building improvements is expected to increase from 100 to 100.6 in one or two years to 101.4 in three or four years and to 135 in more than 150 years. Annual investment is a small portion of total building stock, and depreciation is low. Hence, a long time is required to raise stock to the equilibrium level although current annual investment is highly sensitive to prices. For stock, therefore, the short run price elasticity is low, but the long run elasticity is higher than might be commonly thought.

A fall in the price of a durable input is assumed to exert the full influence on annual investment in one or two years. For any of the inputs analyzed, a 10 percent fall in the input price will increase annual investment from an index of 100 to approximately 110. The sustained increase in annual investment increases stock only one or two percent in the short run, but by 10 percent in the long run. For building improvements, the long run is many years, however.

The contribution to output from a durable asset approximately is proportional to stock. Assuming the elasticities of production are equal for operating and durable inputs, the operating inputs would be responsible for the greater portion of supply (farm output) response to a change in farm prices in the <u>short run</u>. This is because operating inputs are more price elastic than durable stock in the short run. The fact that <u>annual</u> investment is sensitive to price changes in the short run is of secondary importance in estimating supply response. In the long run, however, durable stocks are responsive to price changes and might be the dominant component of long run farm product supply elasticity.

Projections of annual investment are made for 1965 assuming net farm income will remain at the 1955-59 average level and that by 1965 durable input prices relative to prices received by farmers will be 10 percent above the 1955 to 1959 average. Annual investment in motor vehicles, machinery other than motor vehicles and building improvements is expected to increase eight, 12 and seven percent respectively above the predicted 1960 level by 1965. These projections indicate a reversal of the downward postwar trend in motor vehicle purchases. The projections depend heavily on assumptions about income and prices.

Three potential sources of the historic increases in machinery and building improvement demand are: (a) prices, (b) financial structure and (c) slowly changing influences reflected by a time variable. Because prices of investment goods have tended to increase relative to prices received by farmers, the results indicate that investment would have decreased due to (a) from 1926 to 1959. However, improvement in financial status because of greater efficiency, lower prices of operating inputs and inflation tended to increase annual investment. For each durable input studied, the influence shifting demand to the right at the most rapid rate was (c). Included in this category are improvements in quality, adaptability and convenience of durables. Other components of the time variable are the gradual awareness by farmers of better management practices and of the profitability and convenience of investment in durable resources.

The supply of farm machinery is analyzed as part of an interdependent system of farm input and output demand and supply equations. The short run supply elasticity approximately is three or greater according to the limited information equation. Thus, supply prices are quite unresponsive to changes in quantity even in the short run. The most important influence on the machinery supply appears to be the price of iron and steel. A one percent increase in the price of iron and steel tends to increase the supply price one percent. The price of non-farm labor is expected to be reflected in the iron and steel price.

Coefficients of variables representing (a) hired labor wages and (b) government farm programs were insignificant in all the equations. The fact that machinery prices and wages have displayed similar time trends precludes precise estimates of the effect of farm labor costs on investment. But because several studies have failed to uncover the hypothesized tendency for farmers to substitute machinery for high priced labor, the original hypothesis needs revision. The substitution may be more complicated than implied by the least squares models. Even if farm labor wages had remained low relative to machinery prices, the substitution of machinery for labor might have occurred rapidly. It is entirely possible that possibilities for increased output, greater convenience and prestige prompted machinery purchases by farmers. This, coupled with the favorable income earning opportunities in the non-farm sector for those who could not afford machinery encourage outmovement of labor. The revised hypothesis explains the substitution of machinery for labor partially in terms of prices, but emphasizes that the relationship is more complex than postulated by the single equations.

The coefficient of the G variable, reflecting the institutional structure of government farm programs, was insignificant. The variable was crudely constructed and is indeed a weak measure of the changing institutional influence of government programs. The effect of government programs also is reflected in the financial variables, prices and income. To the extent government policies increase income, they are also influential in encouraging investment. Whether the resulting investment and consequent substitution of machinery for labor creates problems of underemployment in agriculture depends on the nature of the farm labor functions, to be examined later.

CHAPTER 9: AGGREGATE INVESTMENT IN PLANT AND EQUIPMENT IN AGRICULTURE

Chapter 9 essentially is an extension of the methodology in Chapter 7 and the empirical applications in Chapter 8. In this study "capital" is divided into two categories: (a) operating or working capital, and (b) durable or fixed capital. Even durable capital is an amorphous classification, however. At times it is necessary to determine the response of electric motor purchases by farmers to changes in prices, and a micro analysis is appropriate. But the necessity for information on macro or scale-of-plant response to price and other conditions suggests the usefulness of combining such diverse elements as electric motors and automobiles into a single category in Chapter 9.

An important purpose of the analysis of aggregate investment behavior in this chapter is to explain the stock of productive assets in functions indicating: (a) demand for other resources such as operating inputs, and (b) the supply of agricultural output. Further it is useful to evaluate the magnitude of price response and rate of adjustment of the agriculture scale of plant to the optimum level. The optimum investment or equilibrium level of stocks might be stated in terms of the entire resource mix in agriculture necessary to maximize returns or bring returns comparable to what similar resources would bring in other economic sectors.

From a broad policy standpoint, problems of underemployment in farming and pressures for labor movements from rural areas are associated with the labor saving investment process in agriculture. Policies to deal with these problems cannot be devised intelligently without knowledge of the effect of "cures" on the agricultural investment process and labor movements. The problems are quite different in under developed areas where investment does not occur rapidly enough, but the same type of information about the investment parameters can be useful in devising strategies to stimulate capital formation.

The procedure in Chapter 9 is to examine the nature of the aggregate investment process; to isolate and determine the quantitative impact of variables that influence annual net and gross investment in agriculture. Least square estimates provide the foundation for empirical inferences of price and income elasticities, historic sources of variation in investment and projections of asset levels to 1965.

Two major non-specific categories of investment are examined in this chapter. The first category is the aggregate investment in the productive portion of farm buildings and improvements and of all farm machinery. This investment aggregate is analyzed for these reasons: (a) it is the aggregate often referred to as "investment in agricultural plant and equipment", (b) it provides a measure of the propensity to invest and other aggregate quantities in which we are interested, yet preserves some properties of homogeneity by excluding human, livestock and feed components of investment, and (c) the analysis is a methodological "proving grounds" for a larger aggregate, the stock of productive assets, because Chapter 8 provides a sizeable amount of information on the elasticities, depreciation rates and other empirical quantities for building improvements and farm machinery.

The second, most inclusive measure of investment in agriculture to be examined in this chapter includes all farm machinery, real estate, livestock, feed and cash held for productive purposes.

Investment in Building Improvements and All Farm Machinery

The logic of the investment process was discussed in detail in Chapter 7 and need only to be reviewed briefly. Annual net or gross investment is considered a function of prices, technology, weather, government programs, external and internal financing capabilities, the interest rate, capital gains and weather. Expectations are undoubtedly important, for the profitability and ability to pay for a durable asset depends on future prices, technology, weather, etc. Theories of risk and uncertainty indicate that farmers base future expectations on past realities, hence it is desirable to include past values of prices and other variables in the investment function. Even if the data were available, it would be desirable to reduce the number of explanatory variables because of the limitations of the least squares statistical model. The analysis in this study is restricted to those few variables found most significant in explaining investment behavior in Chapter 8, and such additional variables as deemed appropriate for specific investment quantities.

Past net farm income concisely represents several expectation influences that are essential elements of the investment function. Since net income may be either invested in productive assets or spent for household items, the variable introduces concepts associated with the firm-household complex. The marginal propensity to invest and to consume may be regarded as a manifestation of the preference or indifference function of the farmer, and perhaps as important, of his wife. At times the distinction between the firm or production sector and the household or consumption sector is not clear. This is especially apparent for farm autos, but is more subtle for farm tractors. Undoubtedly, many farm tractors add more to farm costs than returns. These uneconomic purchases of a "productive" asset might very well be classified as consumption expenditures because the purchase is similar to expenditures for household appliances providing comfort and convenience. These considerations do not necessarily lead to a different specification of the investment function, but suggest caution in interpretation of the coefficients as "marginal propensities to invest in productive assets".

Since expectations and adjustments are important features of the investment process in agriculture, it is desirable to combine adjustment models such as G, I and J with the expectation models B or C from Chapter 7. A more accurate estimate of stock than of annual gross investment is available for all productive assets, hence, models I and J are useful. These models are based on the assumption that farmers adjust gradually to the equilibrium level of stock on the basis of expected income, prices and other variables. The dependent variable is net investment (first differences of total stock), and is a sensitive measure of investment behavior. In addition, models I and J are more amenable to estimation of the elasticities of stock with respect to income and prices than are models with gross annual purchases as the dependent variable.

Estimates of <u>gross</u> and <u>net</u> investment in building improvements and machinery are available, hence, functions are estimated using each as the dependent variable as a test of the comparability of models such as G and J and as a prelude to the estimate of net investment in all productive assets. Equations are estimated in original values only because net investment is sometimes negative and not suited for the logarithm transformation. Net investment is a first difference, consequently, an additional first difference transformation is not appropriate. Also, equations estimated in original values in Chapter 8 are quite adequate.

The variables

The variables specified in the investment function are defined as follows:

Q_{It} The first dependent variable is the national aggregate expenditure on building improvements (including fences, windmills, wells and dwellings not occupied by the farm operator), motor vehicles (40 percent of automobile purchases) and other farm machinery and equipment (4, 120, 121). The variable is intended to measure the productive portion of the purchases and is in millions of 1947-49 dollars. It is Q_{BI} and Q_M from Chapter 8 weighted by 1935-39 prices prior to 1940; 1947-49 prices after 1940.

S_{It} The stock of farm buildings and all farm machinery on farms on January 1 of the current year (4, 114, 121). The variable is in millions of 1947-49 dollars.

ΔS_{It} A second dependent variable is the change in investment stock during the current year, i.e. $S_{It+1} - S_{It}$, measured in millions of 1947-49 dollars.

$(P_I/P_R)_t$ The current year index of the ratio of the price of all farm machinery and building materials to prices received by farmers for crops and livestock (120); 1947-49 = 100.

E_{t-1} The past year ratio of proprietors' equities to total liabilities in agriculture (4, 123).

Y_{Ft} The net income of farm operators from farming during the current year, deflated by the index of prices paid by farmers for items used in production, including interest, taxes and wage rates (120, 121). Net income includes cash receipts, government payments and non-money income less production expenses in millions of 1947-49 dollars. Lagged values of income are also specified in the investment function.

Y_{DFt-1} The declining three year arithmetic average of Y_F. Past year income t-1 is weighted by 0.50, the previous year t-2 by 0.33, and the year t-3 by 0.17.

Y_{AFt-1} The simple past four year arithmetic average of Y_F.

Y_{WFt-1} The increasing arithmetic average of Y_F. Y_{Ft-2} is weighted by 0.16, Y_{Ft-3} by 0.33 and Y_{Ft-4} by 0.50 (see Model D, Chapter 7).

T Time, and index composed of the last two digits of the current year.

All variables in Tables 1 and 2 are annual data for the U.S. from 1926 to 1942 and 1948 to 1959. In Table 3, vari-

Table 1. Annual gross investment in all farm machinery and building improvem with annual data from 1926 to 1959, omitting 1942 to 1947; coeffici and related statistics are included[a]

Equation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_I/P_R t	Y_F t-1	Y_F t-2	Y_{DF} t-1
1	B	0.984 0.981	1.55	887.92	-11.65 (1.19)			
2	A	0.959 0.953	1.09	-348.11	-11.54 (2.15)	0.117 (0.027)		
3	A	0.973 0.968	1.04	-455.08	-10.79 (1.78)	0.063 (0.027)	0.072 (0.020)	
4	C	0.977 0.975	1.06	-467.05	-10.74 (1.50)			0.142 (0.019)
5	D	0.983 0.981	1.24	-226.87	-11.78 (1.19)			
6	BF	0.986 0.982	1.60	785.98	-10.23 (1.33)			
7	F	0.976 0.972	1.39	93.15	-8.66 (1.82)	0.054 (0.026)		
8	G	0.960 0.953	1.17	-491.68	-10.94 (2.28	0.123 (0.028)		

[a]Sources and composition of the dependent variable Q_I and the indicated text.

[b]Estimated only from original observations. Adjustment and expectation

[c]The Durbin-Watson autocorrelation statistic d'.

chinery and building improvements Q_I estimated by least squares
itting 1942 to 1947; coefficients, standard errors (in parenthesis)

Y_F t-1	Y_F t-2	Y_{DF} t-1	Y_{AF} t-1	E t-1	T	Q_I t-1	S_I t
				1.74	38.00		
				(0.19)	(5.62)		
0.117					63.10		
.027)					(6.27)		
.063	0.072				58.62		
.027)	(0.020)				(5.31)		
		0.142			56.91		
		(0.019)			(4.72)		
			0.135		55.07		
			(0.015)		(4.09)		
				1.33	33.05	0.188	
				(0.27)	(5.87)	(0.095)	
.054					39.92	0.41	
.026)					(7.55)	(0.10)	
.123					55.88		0.017
.028)					(10.73)		(0.021)

ariable Q_I and the indicated independent variables are discussed in the

Adjustment and expectation models are presented in Chapter 7.

d'.

Table 2. Annual net investment in all farm machinery and building improvements with annual data from 1926 to 1959, omitting 1942 to 1947; coefficient and related statistics are included[a]

Equation and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	P_I/P_R t	Y_F t-1	Y_F t-2	Y_{DF} t-1
10	BJ	0.944 0.934	1.35	1297.26	-10.28 (1.35)			
11	AJ	0.924 0.907	1.10	189.12	-9.36 (1.90)	0.049 (0.028)	0.056 (0.021)	
12	CJ	0.932 0.920	1.16	196.27	-9.38 (1.63)			0.110 (0.020)
13	DJ	0.944 0.934	1.30	429.01	-10.35 (1.34)			

[a]Sources and composition of the dependent variable ΔS_I and the indicated i in the text.

[b]Estimated only in original observations. Adjustment and expectation model

[c]The Durbin-Watson autocorrelation statistic d'.

machinery and building improvements ΔS_I estimated by least squares
9, omitting 1942 to 1947; coefficients, standard errors (in parenthesis)
ed[a]

$/P_R$ t	Y_F t-1	Y_F t-2	Y_{DF} t-1	Y_{AF} t-1	E t-1	T	S_I t
.28					1.34	37.85	-0.113
.35)					(0.21)	(8.20)	(0.014)
.36	0.049	0.056				48.98	-0.100
.90)	(0.028)	(0.021)				(8.97)	(0.017)
.38			0.110			48.52	-0.102
.63)			(0.020)			(8.05)	(0.016)
.35				0.107		50.46	-0.111
.34)				(0.017)		(6.97)	(0.014)

ent variable ΔS_I and the indicated independent variables are discussed

ns. Adjustment and expectation models are presented in Chapter 7.

istic d'.

Table 3. Annual net investment in all farm machinery and building im substituted for the current price variable used in Table 2; parenthesis) and related statistics are included for least from 1926 to 1959 and from 1913 to 1959, omitting 1942 to 1

Equation, time period and model[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	Y_F t	Y_F t-1	Y_F t-2
14 BJ	(1926-59)	0.909 0.893	1.70	-685.76	0.130 (0.025)		
15 AJ	(1926-59)	0.912 0.892	1.34	-1634.91	0.116 (0.027)	0.082 (0.027)	0.032 (0.024)
	(1913-59)	0.756 0.721	1.98	-1473.88	0.122 (0.029)	0.057 (0.032)	0.030 (0.027)
16 CJ	(1926-59)	0.917 0.902	1.42	-1607.16	0.119 (0.025)		
	(1913-59)	0.775 0.750	2.06	-1473.91	0.119 (0.026)		
17 DJ	(1926-59)	0.918 0.900	1.51	-1582.25	0.120 (0.025)		
	(1913-59)	0.801 0.773	2.35	-1453.58	0.131 (0.026)		
18 DJ	(1926-59)	0.913 0.898	1.71	-1546.20	0.131 (0.024)		
	(1913-59)	0.800 0.778	2.29	-1458.33	0.125 (0.022)		

[a]Sources and composition of the dependent variable ΔS_I and the i

[b]Estimated only from original observations. Adjustment and expec

[c]The Durbin-Watson autocorrelation statistic d'.

improvements ΔS_I with current net income
2; coefficients, standard errors (in
t squares estimates from annual data
1947 in each series[a]

	Y_{DF} t-1	Y_{AF} t-1	Y_{WF} t-1	E t-1	T	S_I t
				1.30	-4.53	-0.054
				(0.29)	(8.82)	(0.019)
!					8.88	-0.046
i)					(8.45)	(0.018)
|					6.54	-0.038
')					(5.35)	(0.020)
	0.113				8.25	-0.048
	(0.023)				(8.05)	(0.018)
	0.097				6.68	-0.043
	(0.027)				(5.06)	(0.019)
		0.188	-0.074		7.81	-0.050
		(0.072)	(0.061)		(8.17)	(0.018)
		0.065	0.035		6.96	-0.055
		(0.079)	(0.067)		(4.82)	(0.019)
		0.104			7.01	-0.052
		(0.022)			(8.24)	(0.018)
		0.105			6.97	-0.053
		(0.024)			(4.78)	(0.019)

indicated independent variables are discussed in the text.

ectation models are presented in Chapter 7.

ables extend from 1913 to 1959, omitting 1942 to 1947 in selected equations for comparison with the results of equations fitted to data for 1926 and later years.

In addition to the variables indicated, the price of operating inputs P_O, the hired farm wage rate P_{HL} and the price of farm inputs P_P individually were specified in the investment function, but the coefficients of the variables were insignificantly different from zero. The influence of operating input and other related input prices perhaps is best expressed in the net farm income variable. Equations were specified including farm size, the short term interest rate and a measure of return on investment in common industrial stock, but the coefficient of each of these variables also was not significant.

<u>Investment equations estimated by least squares</u>

Current price, net income, the equity ratio and time explain a large proportion of the annual variation in gross annual investment according to the results indicated in Table 1. The coefficients of P_I/P_R, E and T are highly significant in equation 1 and the coefficient of determination between Q_I and the three variables is 0.98. According to the Durbin-Watson statistic (d' = 1.55), the hypothesis that the residuals are uncorrelated is not rejected at the 95 percent probability level. Interpreting E as the culmination of the income generating process, capital gains, and as a measure of financial position representing both the willingness of farmers to invest and also the willingness of external sources to lend funds, equation 1 is a simple but meaningful expression of the investment process.

Equations 2 to 5 are included to illustrate the role of net income in the investment process. As additional lags are introduced, the R^2 increases. The sum of the income coefficients in equations 2, 3 and 4 increases from 0.117 to 0.135 to 0.142 as additional lags are added. It appears that the marginal propensity to invest (income coefficient) would be increased very little by additional income lags. The four year simple arithmetic income average in equation 5 increases the R^2 slightly, but the marginal propensity to invest is slightly less. Originally, the equation was estimated as the Ladd-Tedford model D, but the coefficient of the weighted income variable Y_{WFt-1} was not significant. The weighted income variable was dropped from the equation.

The coefficient (1-g) of the lagged annual gross investment Q_{It-1} is significantly greater than zero in equation 7 and indicates that the adjustment coefficient may be less than one. Equation 6 gives a different result and indicates that the adjustment coefficient is unitary or nearly unitary. If expectation variables are adequately specified as in equation 6, there appears to be no pressing need for the adjustment model of annual purchases. That is, if farmers and external credit sources are satisfied with the current financial and price structure, and are subjectively certain of favorable future earnings, little time is required to adjust to the equilibrium level of <u>annual purchases</u>. Although little time is required to adjust to the desired level of annual investment, the time required to adjust to the equilibrium level of stock may be long. Model G (equation 8), included to determine the nature of the long run adjustment to equilibrium stock, indicates that the adjustment and depreciation coefficients are of equal magnitude. Since the coefficient of lagged stock, h-g, statistically does not differ from zero, the implication is that the adjustment and depreciation rates are equal. If the depreciation rate is 0.10, the adjustment rate also approximately is 0.10.

On the basis of the equations in Table 1, annual investment Q_I can be expressed adequately without lagged annual investment or stock. It is interesting to note that the long run coefficients in equation 6, found by dividing the short run coefficients by the adjustment coefficient 0.81, is -12.6 for $(P_I/P_R)_t$ and is 1.64 for E_{t-1}. The similarity of these coefficients to the respective estimates -11.65 and 1.74 in equation 1 implies that the error introduced into estimates of short or long run elasticities from ignoring the adjustment of annual purchases to equilibrium is small.

Net investment is the dependent variable in the equations presented in Table 2. The relationship between net investment ΔS_{It} and gross investment Q_{It} is evident from the identity

(9) $$\Delta S_{It} = Q_{It} - h\, S_{It}$$

where h is the rate of depreciation. Gross investment is always positive, but if $Q_{It} < h\, S_t$, net investment is negative. If the depreciation allowance $h\, S_{It}$ is nearly constant through time, the magnitude of the coefficients for comparable variables in Tables 1 and 2 should be similar. Of course, S_{It} is not constant through time. Q_{It} and S_{It} are increasing functions of time and subtraction of the replacement or depreciation allowance from Q_{It} tends to reduce the absolute magnitudes of the coefficients.[1] Thus, the coefficients are nearer zero in Table 2 than in Table 1. An adjustment is made in the coefficients to insure comparability of elasticity estimates in subsequent analysis.

Aside from the fact that the R^2's are lower in Table 2 than in Table 1, the results are reassuringly similar. This similarity is preserved although the dependent variable ΔS_I is the first difference of a stock variable based on somewhat dubious data. Because of initial errors and additional errors

[1]Subtraction of a quantity essentially proportional $(0 < h < 1)$ to the dependent variable is similar to dividing the dependent variable by a constant and, of course, moves the coefficients of the independent variables toward zero.

introduced in construction of the stock data, changes in the depreciation rate h, etc., the identity in equation 9 is not satisfied. But the underlying assumptions are met to an adequate degree and the least squares model I is sufficiently vigorous to overcome shortcomings in the data. The R^2's in Table 2 are relatively high considering that the dependent variable is a first difference of stock.

The coefficients of lagged stock are negative and significant. The coefficient may be interpreted as: (a) the coefficient of adjustment (model I), (b) the coefficient of depreciation (model J), (c) a positivistic expression of farmers' desire to reduce annual purchases when stocks are high, and (d) the cumulative influence of variables correlated with stock but not included in the equation such as farm size, amount of liquid assets, technological advances and improved knowledge of the profitability and convenience of greater investment. These interpretations are not mutually exclusive, of course. Fortunately, the model G, Chapter 8 and Table 1, Chapter 9, indicate that the adjustment and depreciation rates approximately are equal. Since the estimates of elasticities and long run equilibrium are not influenced by the interpretation, it is not necessary to specify whether the equations in Table 2 are model I or J. A depreciation rate of 0.10, indicated by equations 11 and 12, is considerably lower than the rate for machinery, but higher than the rate for building improvements. Thus, there is no basis for rejecting the estimate as unrealistic. Because of interpretations (c) and (d) above, the coefficient of lagged stock is expected to be biased toward zero. That is, it is likely that the net influence on investment of variables correlated with lagged stock but excluded from the equation is positive. Because the long run coefficients are found by dividing the price and income coefficients by an adjustment coefficient biased toward zero, the estimated coefficients probably represent the upper boundary of long run response to price and income.

Prices of investment items are not always available, and it sometimes may be useful and meaningful to substitute income for a price variable such as $(P_I/P_R)_t$. Several advantages of doing so in Table 3 are: (a) adequate measures of P_I/P_R and E are not available for earlier years; substitution of Y_F permits estimation of the equations back to 1913, (b) the use of income rather than price permits a measure of the total marginal propensity to invest out of net income, and (c) use of current net income rather than P_I/P_R may reduce the ambiguity in interpreting results. That is, price and income variables are related because of the common element P_R in each and because P_I tends to be correlated with many of the prices P_P paid by farmers for items used in production which implicitly are included in net farm income. Because of the collinearity among input prices, interpretation of the influence of P_I on investment is difficult -- the elasticity of investment with respect to P_I may, in fact, be the elasticity with respect to P_P. Of course, if the price of investment durables is the relevant short run decision variable as implied in Tables 1 and 2, substitution of Y_F for P_I/P_R is not appropriate. It is hoped that the results in Table 3 will help clarify this question of specification.

The significance of the income coefficient, multiple coefficient of determination and magnitude of the coefficient of lagged stock S_{It} are less satisfactory when Y_{Ft} is substituted for $(P_I/P_R)_t$ in Table 3. The more acceptable results in Table 2 than in Table 3 support the hypothesis that the price of durable investment items are important in the investment decision function. Equations not shown indicate that lagged price variables P_I/P_R are overshadowed by adequately specified income variables. It is possible to go a step further and state that the results support the hypothesis that the price of durable investment items is important in the decision framework, but only in the short run. The realistic implication is that because the price of the durable item is of historic interest after the investment decision is made, expectations based on past prices are not important. But because the important concern is the ability to pay for the newly acquired asset out of future earnings, expected earnings reflected by past net farm income is an important element in the investment function.

The coefficients of income in equation 15 decline at an "orderly" rate and indicate that additional lags would add little to the explanation of investment. The similarity of the results in equations 15 and 16 also gives assurance that additional income lags are unnecessary. Equation 17 is Ladd-Tedford model D with a four year income lag. The coefficient of $Y_{WF\,t-1}$ is not significant, hence, the variable is deleted to form equation 18. The implication is that income of each of the past four years exerts an equal influence on current investment. Equation 16, which depicts a declining income influence, gives a larger R^2 and coefficient of past income, and is a more reasonable expression of the investment function than equation 18. Model DJ was also estimated with a three year income lag. The results were very similar to those in equations 17 and 18, hence, are not presented.

Equations for both time periods consistently indicate that the marginal propensity to invest is 0.2. The implication is that a sustained rise of one million dollars in net income eventually will increase annual net investment in plant and equipment 200 thousand dollars in agriculture.

Price and income elasticities

Equations in Table 1 ideally are suited for estimating the elasticity of gross annual investment (annual purchases). Equations in Tables 2 and 3 are best suited for estimating the elasticity of demand for investment stock. As anticipated, the price elasticities of demand for Q_I are similar to those computed for machinery Q_M and building improvements Q_{BI} in Chapter 8 and need little further discussion. The elasticity of Q_I with respect to P_I computed from equation 4 is -0.76. The elasticity of annual purchases with respect to P_R computed from the same equation is 0.76 in the short run (current and past year) and 2.3 in the long run (three or four years). Equation 6 indicates that the adjustment of annual purchases to the desired level substantially is complete in four years.

According to the estimates in Table 4, the demand for stock of machinery and building improvements is highly inelastic in the short run. Stock is very responsive to price changes in the long run, but if the adjustment coefficient is 0.11, only 90 percent of the total adjustment is completed in 20 years. Equations 1, 4, 10 and 12 indicate that the elasticity of investment stock S_I with respect to P_I approximately is -0.1 in the short run, -0.7 in the long run. From the same equations, the elasticity of S_I with respect to P_R approximately is 0.1 in the short run, 0.2 in the intermediate run and 2.0 in the long run. The results also indicate that

Table 4. Elasticities of investment demand for the aggregate S_I with respect to price and net farm income compute

Equation	Model	Dependent variable[e]	Short run[b] (1-2 years) P_I	P_R	Inter (3 P_I
1	B	Q_{It}	-0.080	0.080	-0.080
4	C	Q_{It}	-0.074	0.074	-0.074
10	BJ	ΔS_{It}	-0.078	0.078	-0.078
12	CJ	ΔS_{It}	-0.071	0.071	-0.071
14	BJ	ΔS_{It}	Y_F 0.073		
16 (1926-59) (1913-59)	CJ	ΔS_{It}	0.067 0.069		

[a]See the text and Tables 1, 2 and 3 for discussion of dat related statistics. Elasticities are computed at the means.

[b]Price elasticities are computed from the coefficient of current income Y_{Ft}.

[c]A one percent change in the parity ratio P_R/P_P is assume farm income (cf. Appendix B). Translation of intermediate run of elasticities is done for convenience, but may impart some u from the model B equations including equity E are computed on t percent in net income will in three or four years cause the equ 15, Chapter 8). The intermediate run elasticity with respect plus the short run price elasticity. Since P_I is not an impor intermediate run elasticities are identical.

[d]The intermediate run elasticities divided by the adjustme

[e]The elasticity estimates are "corrected" for the non-com h S_{It} to the mean of $\bar{S}_{It+1}$ in equations 1 and 4, because the de than $S_{It+1} - S_{It}$.

[f]Assumed adjustment coefficients, based on Table 2. The the adjustment to equilibrium at the annual adjustment rate g i approximately 20 years are required to make 90 percent of the t

the aggregate stock of farm machinery and buildings
income computed from the equations in Tables 1, 2 and 3[a]

b) P_R	Intermediate run[c] (3-4 years) P_I	P_P	P_R	Long run[d] (many years) P_I	P_P	P_R	Adjustment or depreciation coefficient
)80	-0.080	-0.16	0.24	-0.73	-1.45	2.18	0.11[f]
)74	-0.074	-0.15	0.22	-0.67	-1.36	2.00	0.11[f]
)78	-0.078	-0.14	0.22	-0.71	-1.27	2.00	0.11
)71	-0.071	-0.13	0.20	-0.71	-1.30	2.00	0.10
—		Y_F			Y_F		0.054
		0.18			3.34		
		0.13			2.73		0.048
		0.13			2.98		0.043

cussion of data, methodology, coefficients, standard errors and
t the means.

oefficient of current price $(P_R/P_I)_t$; income elasticities from

$_R/P_P$ is assumed to be associated with a two percent change in net
termediate run elasticities of E and Y_F to prices by multiplication
impart some upward bias to the results. The price elasticities
e computed on the assumption that a sustained increase of one
s cause the equity ratio to increase 1.57 percent (cf. equation
with respect to P_R is the price P_R component of income or equity
s not an important component of equity or income, the short and

by the adjustment coefficient g.

or the non-comparability of the dependent variables by adding
because the dependent variable is $S_{It+1} - S_{It} + h\ S_{It}$ rather

Table 2. The number of years N required to make T proportion of
stment rate g is $N = \frac{\log(1-T)}{\log(1-g)}$. If the adjustment rate is 0.11,
ercent of the total adjustment.

stock is quite responsive to changes in prices paid by farmers P_P in the long run -- the elasticity is about -1.3. Equity and net income in equations 1, 4, 10 and 12 are translated to prices by the definitional equation 15, Chapter 8, and equation 1, Appendix B. Since price ratios are used throughout, the investment functions are homogeneous of degree zero in prices.

Due to the similarity of response of annual investment to price changes, inferences about the aggregate may be extended to the components of Q_I, i.e. Q_M and Q_{BI}. But because of the lack of uniformity in depreciation rates, adjustment rates and ratios of annual purchases to stock, it is indeed unwise to generalize results of the aggregate functions in Table 4 for machinery stock S_M and building stock S_B. The equations in Table 2 indicate that the depreciation or adjustment rate for the aggregate investment function is 0.11. The rate for machinery is considerably greater than this figure and for building improvements is considerably less than this estimate on the basis of the results in Chapter 8.

Equations 14 and 16 provide the basis for estimating the income elasticity of demand for investment stock. Because current net income does not appear to be an adequate substitute for prices, and because the equations in Table 3 are inferior in other respects to those in Table 2, the derived income elasticities should be regarded as tentative estimates. The income elasticity of stock demand is 0.07 in the short run, 0.1 or 0.2 in the intermediate run and approximately 3.0 in the long run according to equations 14 and 16. These estimates, particularly the long run estimates, appear to be unusually large. One reason is that the adjustment coefficients are low. Since the intermediate run elasticities are divided by the adjustment coefficient to form the long run elasticities, the long run elasticities are inversely related to the size of the adjustment coefficient. The adjustment coefficients are expected to be biased toward zero because of correlations with variables exerting a positive influence on net investment. Thus, the elasticity estimates represent the upper boundary of anticipated response.

Shifts in investment

Equation 1 provides the basis for estimating sources of shifts in annual investment Q_I from 1926 to 1959. The results are similar to those depicted in Table 6, Chapter 8, and can be given a cursory discussion. The actual increase in annual investment from 1926 to 1959 was 105 percent and equation 1 depicts a 108 percent increase. Thus, there is little apparent error: the equation only slightly overestimates the actual increase. Equation 1 indicates that had the price P_I/P_R been at the 1959 level in 1926, annual investment would have been 60 percent less than the predicted demand. If the financial or equity position E had been at the 1959 level in

1926, *ceteris paribus*, the predicted demand quantity would have been 69 percent greater. The price and financial influences nearly offset each other. If the price and equity variables are set at the 1926 level, equation 1 depicts a 99 percent increase in demand by 1959 due to the slowly changing forces represented by the time variable T. The results emphasize again the importance of improved machinery, increased knowledge by farmers, and related influences tending to increase farm investment. The replacement demand is ignored in the equation. If the adjustment and depreciation rates are equal as indicated by equation 8, the "adjustment quantity" and replacement demand are offsetting, and both may be ignored according to model G.

Trends and projections

Figure 1 illustrates the historic relationship between annual gross investment Q_I and stock S_I. The two series displayed similar trends during the postwar period. It is not surprising that annual investment was much greater in 1948 than in 1941. That stock increased appreciably during the period is surprising, however. Apparently, farmers obtained sufficient quantities of investment items to more than replace depreciated stock during the 1942 to 1947 period. Despite the downward trend in annual investment in the postwar period, stock continued to increase rapidly because annual

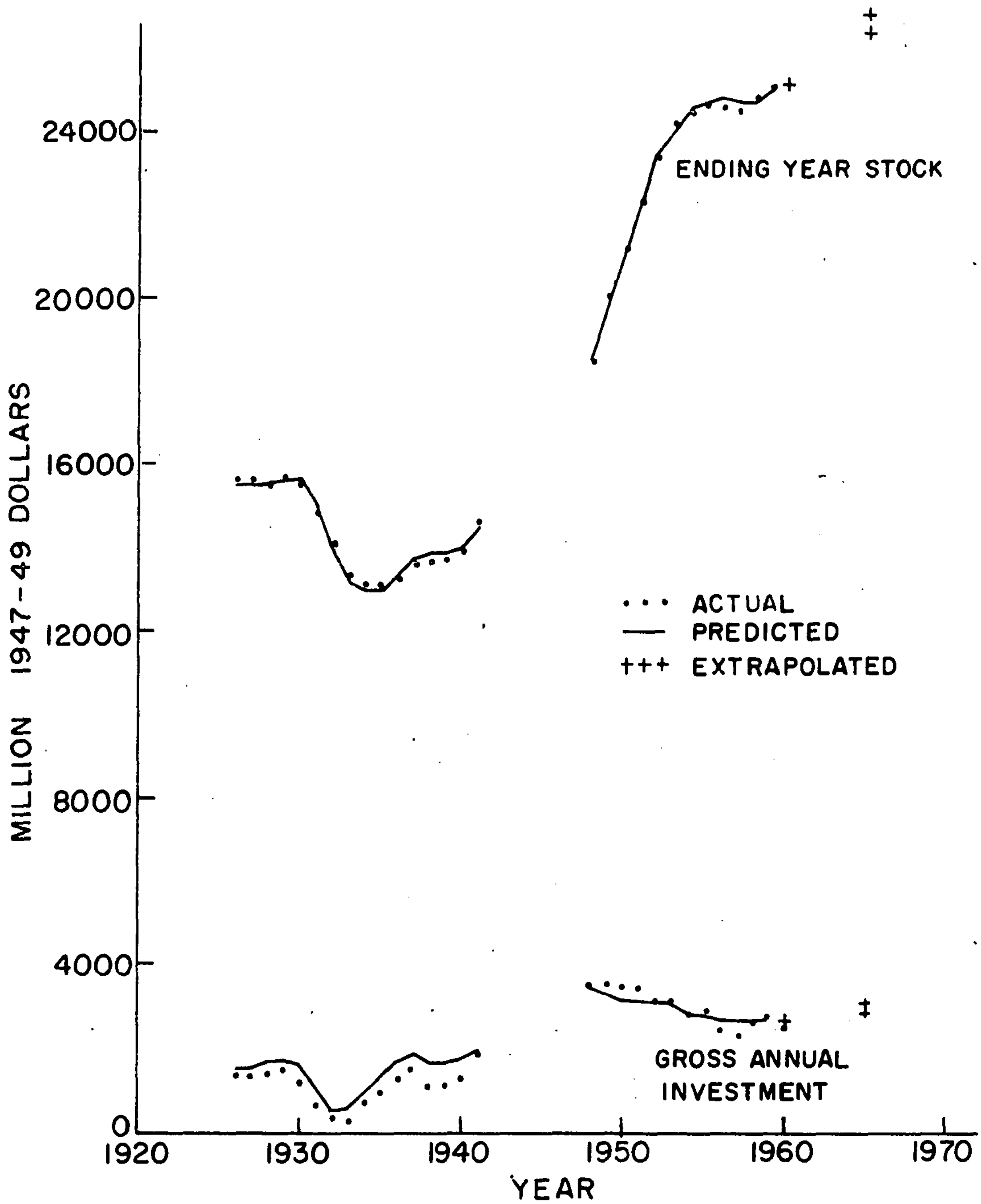

Figure 1. Trends in ending year stock S_I and gross annual investment Q_I in all farm machinery and building improvements from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 12

investment was considerably greater than replacement requirements. By 1955, annual purchases approached replacement requirements, and total stock began to level off. In 1956 and 1957, depreciation was greater than purchases, and the stock of durables S_I declined.

Equation 12 predicts total ending year stock $S'_{I\,t-1}$ by equation 20

(19) $S_{I\,t+1} - S_{It} = \Delta S_{It}$ (20) $S'_{I\,t+1} = \Delta S'_I + S_{It}$

where S'_{It} is the change in stock predicted by equation 12 and S_{It} is the known beginning year stock. (The notation "t+1" is used because the "ending year" stock actually is the January 1 stock of the following year t+1.) The predicted annual gross investment Q'_{It} is computed from identity equation 9 as

(21) $$Q'_{It} = \Delta S'_{It} + h\, S_{It} \;.$$

The depreciation rate h is the coefficient of lagged stock according to model J. Figure 1 indicates that equation 12 predicts well in the postwar years, but the depreciation rate appears to be low in the prewar years. A fixed rate h may be too rigid an assumption for the years covered by the data; the depreciation rate may be declining. Equation 12 predicts annual investment more accurately in recent years than did the equations used to predict Q_M and Q_{BI} in Chapter 8. The error is small in extrapolating gross investment to 1960 from data outside the range of observations to which the equation was fitted. The equation predicts stock very well. Because of the technique used to estimate stock, rather large errors in predicting changes in stock would not appear large in the upper graph of S_I. The actual estimate of stock for 1960 (January 1, 1961) is not available and could not be checked against the extrapolated estimate.

Equation 12 provides the structure for projecting estimates of investment stock and purchases to 1965. The term "projection" is used because assumptions must be made about the price and income level in 1965. The first projection, based on the assumption that net income and prices will remain at the 1955-59 average level, indicates that annual gross investment will be 12 percent, stock six percent above predicted 1960 levels by 1965. A second, lower and more realistic projection is based on the assumption that net income will remain at the 1955-59 average but that the relative price of investment items P_I/P_R will increase 10 percent by 1965, the increase being spread proportionately over the period. Based on these assumptions gross annual investment is projected to be eight percent greater, stocks five percent greater than predicted 1960 levels by 1965. Annual investment is projected to be 10 percent greater than predicted 1960 levels by 1965 under the same assumption but from equation 4 with Q_I the dependent variable. The results consistently depict an increasing trend for annual investment and stocks by 1965. The projections are highly sensitive to the underlying assumptions and the reader may wish to examine the changes in projections under alternative price and income assumptions. The standard error of the projected estimates were not computed but would be large for distant extrapolations.

Investment in All Productive Assets on Farms

The most highly aggregated measure of farm investment used in this study is all productive assets on farms. The measure includes machinery, real estate, livestock, feed and cash held for use in production. The specification of the investment function is similar for productive assets and for machinery and building improvements, discussed earlier in the chapter. Some notable differences are apparent, however. The price of productive assets is not available and is not constructed for the study. Perhaps a market price is not meaningful because many of the components are produced on farms and have only an imputed price. A quantity representing the imputed price is net farm income. That is, net farm income is the residual after paying production costs, and is the approximate return on durable assets and family labor (assuming constant returns to scale). If farmers ignore the family labor component, and subjectively impute the entire residual return to durable assets, then net income is a logical measure of the imputed price of productive assets.

The argument for inclusion of past output in the investment function for all productive assets is based on a fixed relationship between asset stocks and output. That is, output may be increased in the short run by substituting more operating inputs into the resource mix. But given time, the farmer restores the old ratio of output to durable capital because of profit considerations and technical conditions. A considerable margin of variation appears to be possible in the ratio of machinery stocks to output because a number of substitutes exist for machinery and some evidence indicates farmers tend to be over invested in machinery. For livestock, feed and cash for production, few substitutes exist, and changes in the ratio of these productive assets to output may only be tolerated in the short run, it may be argued. Sufficient grounds exist to account for the accelerator effect by including past output in the investment function. It is difficult to distinquish the amount of feed, livestock and cash held for productive purposes from the amount held for markets which are anticipated to improve in the future. For this reason, considerable error may be expected in the data.

Because livestock and feed inventories are sensitive to weather conditions, it seems desirable to include a measure of weather in the investment function. Theoretically, the decision to invest is a function of the discount rate as well as expected future returns. Two measures of the discount rate were included in the investment function: (a) the short term interest rate on loans to farmers, and (b) the rate of return on industrial common stock. These rates were included directly in the investment function and also as ratios to the rate of return on investment in agriculture (residual farm income divided by the total farm assets). But the coefficients of all these variables were non-significant.

Because estimates of gross annual investment are not available, but estimates of stock are contained in secondary sources, model I or J is appropriate.

<u>The variables</u>

The following variables are included in the investment function:

S_{pt} The stock of productive assets on farms January 1 of the current year (4, 123). The variable includes machinery, real estate, feed, livestock and cash inventories held for productive purposes and is measured in 10 millions of 1947-49 dollars.

ΔS_{pt} The dependent variable is the net annual investment in productive assets, i.e., the change in total stock during the current year. It is the first difference of the foregoing variable S_p.

Y_{Ft} The net income of farm operators from farming during the current year, deflated by the index of prices paid by farmers for items used in production, including interest, taxes and wage rates (120, 121). Net income includes cash receipts, government payments and non-money income less production expenses in millions of 1947-49 dollars.

Y_{DFt} The declining three year arithmetic average of Y_F. Current year income Y_{Ft} is weighted by 0.50, the past year Y_{Ft-1} by 0.33 and the previous year Y_{Ft-2} by 0.17.

Y_{AFt-1} The simple past four year average of Y_F.

O_{t-1} Farm output during the past year in millions of 1947-49 dollars (4).

$\bar{O}_{t-1}$ Simple average of farm output O of the past two years.

W_t Stalling's index of the influence of weather on farm output in the current year (108, 124). Stalling's data extend only to 1957. Observations for 1958 and 1959 are computed from the deviations from a linear yield trend.

T Time, an index composed of the last two digits of the current year.

All variables are aggregate annual observations for the U.S. from 1913 to 1941 and from 1948 to 1959 except $\bar{O}_{t-1}$ which was not computed for 1913 to 1925. As indicated earlier, additional variables such as the return on investment in common industrial stock and the short term interest rate were included in the investment function, but the coefficients were not significant. Also, first differences of income and output variables were included in the functions but did not significantly improve the explanation of net investment. Depending on what variables are specified in the function, the coefficient of farm size may be significant. But because of the high correlation between beginning year stock and farm size, the latter variable is excluded from the investment function.

Investment equations estimated by least squares

Income, weather, time and beginning year stock explain 70 percent of the variation in annual net investment according to equation 22, Table 5. Current year income reflects an unusual proportion of the total influence of income on annual investment. Some least squares bias is suspected, that is, Y_{Ft} and the errors in the dependent variable are correlated. The income variable in equation 23 which forces the influence of income to be spread over three years is intuitively more appealing and consistent with the results of the foregoing investment studies. The time variable is insignificant in the equations estimated from 1926 to 1959 data. Gradually changing technological, educational and other influences probably are absorbed by the beginning year stock variable.

Table 5. Annual net investment in productive farm assets ΔS_p estimated by from 1926 to 1959 and 1913 to 1959, omitting 1942 to 1947 in ea standard errors (in parenthesis) and related statistics are incl

Equation and years[b]		R^2 and $\bar{R}^2$	d'[c]	Constant	Y_{F_t}	Y_{DF_t}	$Y_{DF_{t-1}}$
22	(1926-59)	0.751	1.67	-142.53	0.0242		0.0083
		0.694			(0.0090)		(0.0077)
	(1913-59)	0.690	1.19	-106.85	0.0261		0.0084
		0.646			(0.0061)		(0.0063)
23	(1926-59)	0.734	1.67	-72.89		0.0305	
		0.687				(0.0066)	
	(1913-59)	0.663	1.20	-67.56		0.0339	
		0.625				(0.0050)	
24	(1926-59)	0.759	1.72	-108.64	0.0234		
		0.704			(0.0084)		
	(1913-59)	0.700	1.19	-67.96	0.0261		
		0.658			(0.0054)		
25	(1926-59)	0.738	1.64	-195.46	0.0309		
		0.692			(0.0065)		
	(1913-59)	0.675	1.19	-166.20	0.0316		
		0.638			(0.0046)		
26	(1926-59)	0.821	2.10	455.13	0.0320		-0.0032
		0.770			(0.0083)		(0.0078)
27	(1913-59)	0.740	1.62	202.71	0.0319		0.0018
		0.694			(0.0061)		(0.0064)
28	(1926-59)	0.778	1.88	412.00		0.0273	
		0.728				(0.0063)	
29	(1913-59)	0.683	1.49	138.37		0.0336	
		0.638				(0.0050)	
30	(1926-59)	0.820	2.05	426.84	0.0295		
		0.779			(0.0056)		
31	(1913-59)	0.739	1.63	205.99	0.0332		
		0.702			(0.0042)		

[a]Sources and composition of the dependent variable ΔS_p and of the ind

[b]Estimated only from original observations. Adjustment models I or J Chapter 7.

[c]The Durbin-Watson autocorrelation statistic d'.

d by least squares with annual data
n each series; coefficients,
included[a]

	Y_{AF} t-1	O t-1	$\bar{O}$ t-1	W t	T	S_p t
3				2.10	3.67	-0.052
7)				(1.19)	(3.64)	(0.040)
4				1.14	2.88	-0.044
3)				(0.88)	(1.32)	(0.025)
				2.42	4.93	-0.067
				(1.17)	(3.50)	(0.025)
				1.38	3.20	-0.052
				(0.90)	(1.34)	(0.025)
	0.0099			2.15	3.73	-0.058
	(0.0072)			(1.17)	(3.58)	(0.040)
	0.0101			1.13	2.98	-0.051
	(0.0058)			(0.86)	(1.30)	(0.025)
				1.99	3.36	-0.042
				(1.19)	(3.64)	(0.039)
				1.09	2.65	-0.033
				(0.89)	(1.32)	(0.024)
			0.043	1.35	-3.19	-0.188
)			(0.015)	(1.06)	(3.96)	(0.059)
		0.0216		0.87	-1.21	-0.114
)		(0.0085)		(0.82)	(2.02)	(0.036)
			0.030	2.10	0.95	-0.175
			(0.014)	(1.10)	(3.78)	(0.062)
		0.0126		1.29	0.96	-0.0971
		(0.0084)		(0.88)	(1.99)	(0.0386)
			0.040	1.44	-2.60	-0.181
			(0.013)	(1.02)	(3.62)	(0.055)
		0.0226		0.85	-1.44	-0.115
		(0.0077)		(0.81)	(1.84)	(0.035)

: indicated dependent variables are discussed in the text.

r J are combined with expectation models discussed in

Over a longer period, the stock variable does not accommodate adequately these changes -- the time variable is significant in equations 22, 23, 24 and 25 for the 1913 to 1959 period. The degree of autocorrelation present in the residuals as evidence by the Durbin-Watson d' statistic is low for the equations estimated from the shorter time series. Structural changes not accommodated in the model appears to be producing some autocorrelation in the residuals of equations estimated from 1913 to 1959, however.

The introduction of the accelerator effect through the lagged output variable appears to reduce autocorrelation and to enhance other properties of the investment equations 26 to 31. The absolute magnitude and significance of the coefficient of the lagged stock variable is increased. Some instability is exhibited in the magnitude of the accelerator coefficient, depending on the form of the output variable. Coefficients of both output variables are significant, but the two year average output variable registers a more sizeable influence on net investment.

Although introduction of the accelerator effect increased the R^2 and reduced autocorrelation in the residuals, it also introduced more collinearity into the equations. In equation 29, for example, the highest simple correlation 0.82 was between S_{pt} and T -- other simple correlations were much lower before introducing lagged output into the equation. The simple correlation between $\bar{O}_{t-1}$ and S_{pt} is 0.93, thus introduction of lagged output in the equation can create problems of coefficient instability, difficulty in interpretation and other features associated with multicollinearity. Despite these problems, the results indicate that lagged output does improve the explanation of annual net investment, and the specification does not seem to be complete without the accelerator.

The units of the dependent variable are ten times as large as the units of income and output. To observe the effect of a one unit increase in income or output on investment, we merely move the decimal point of the respective coefficients one place to the right. The results indicate that the "marginal propensity to invest" out of net income is approximately 0.3. This does not mean that thirty cents is invested by farmers from every dollar of net income. The interpretation is much less precise. The results indicate that a sustained one million dollar increase in net income eventually will increase annual investment 300 thousand dollars or more in U.S. agriculture. The term "or more" is used because an additional recursive influence on investment comes through the accelerator. There is a direct influence of net income on investment from the explicitly specified income variables in the equations, and an indirect influence because favorable farm prices increase farm output, causing additional investment through the accelerator effect. The relationship between income and investment also is indirect because: (a) the measure of income Y_F used in this study includes non-money income, for example, and other concepts of income would result in other estimates of the marginal propensity to invest, (b) many components of S_p are farm produced rather than cash purchases, and additional net income may first be invested in operating inputs, for example, before inventories of livestock and feed are increased, and finally (c) external credit sources provide some funds for investment in agriculture because net farm income is favorable.

Price and income elasticities

Table 6 illustrates the price and income elasticities of stock S_p with respect to prices and net income computed from the equations in Table 5. The income elasticities are translated into price elasticities by the definitional equation 1, Appendix B. The equation indicates that a one percent increase in the parity ratio has been associated with a two percent increase in net income. The elasticities with respect to prices paid P_P are the elasticities given for P_R/P_P but with a negative sign. The results indicate the price or income elasticity of stock is low in the short run. A sustained one percent increase in net income increases the stock of productive assets only 0.02 percent in the short run;

Table 6. Elasticities of investment demand for the stock of all productive assets S_p with respect to price and net farm income computed from the equations in Table 5[a]

Equation and year	Short run (1-2 years)		Intermediate run (3-4 years)		Long run (many years)		Adjustment or depreciation coefficient
	Y_F[b]	P_R/P_P[c]	Y_F[b]	P_R/P_P[c]	Y_F[d]	P_R/P_P[d]	
23 (1926-59)	0.017	0.035	0.035	0.069	0.52	1.03	0.067
23 (1931-59)	0.019	0.039	0.039	0.077	0.74	1.49	0.052
28 (1926-59)	0.016	0.031	0.031	0.062	0.20	0.39	0.175
29 (1913-59)	0.019	0.038	0.038	0.077	0.41	0.82	0.097

[a]See the text and Table 5 for discussion of data, methodology, coefficients, standard errors and related statistics. Elasticities are computed at the means.

[b]Computed from the declining three year average net farm income variable Y_{DFt}, which implies that one-half the elasticity is attributed to the current year.

[c]Translated from the definitional equation 1 in Appendix B which indicates that a one percent rise in the price ratio P_R/P_P is associated with a two percent rise in net farm income in the 1946-59 period (cf. equation 1, Appendix B).

[d]Found by dividing the intermediate run elasticity by the adjustment coefficient g. If the adjustment coefficient is 0.10, over 20 years are required to make 90 percent of the total long run adjustment.

0.04 percent in the intermediate run. Although demand for stock is highly inelastic in the short run because of the time and money required to increase livestock, feed and other inventories, demand is considerably more responsive in the long run. The long run elasticities are computed by dividing the intermediate run elasticities by the coefficient of lagged stock. Because the coefficient is somewhat unstable, there is a lack of uniformity in estimates of long run elasticities among equations. In general, the results indicate that a sustained one percent increase in income Y_F will increase investment stock one half of one percent in the long run. Similarly, a one percent sustained increase in P_R (decrease in P_P) in the long run is expected to increase the level of investment stock one percent. The "long run" is distant, however. Twenty-two years are required to make 90 percent of the long run adjustment if the adjustment rate is 0.10. The results from equation 3, Chapter 11, are used to determine the influence of prices on output, and this accelerator influence is added to the elasticities computed from equations 28 and 29.

Shifts in investment

The stock of productive assets S_p was 30 percent greater in 1959 than in 1926. Stock at the end of a given year is the sum of the carryover from the past years plus annual investment. The principal reason 1959 stock was greater than 1926 stock was because a much larger volume of inventories was carried over into 1959. To determine why carryover was greater, it is necessary to trace through time the pattern of gross annual investment, since stock is the culmination of the annual investment pattern. Analysis of the individual influences of income and other variables on investment for each intervening year from 1926 to 1959 would be a cumbersome process indeed. To gain some insight into the annual investment process, equation 22 is assumed to be model J, and the influence of income and the time variable on annual investment is compared for the two extreme years only. It is likely that the types of influences registered for these years will also provide some insight into a comparison of annual investment behavior between other years.

According to equation 22 (1926-59) gross annual investment in 1959 was 42 percent greater than in 1926. If net farm income had been at the 1959 level in 1926, <u>ceteris paribus</u>, the equation indicates that demand would have been only seven percent greater. Setting only the time variable at the 1959 value, leaving other variables at 1926 values, the equation depicts a 27 percent increase in demand. The discrepancy between the total percentage increase in demand and the sum of the percentage increases due to income and time is explained by the difference in the weather variable.

There is little doubt that some of the 27 percentage increase attributed to time in equation 22 could be associated with the accelerator effect, or farm output. To test this hypothesis, sources of the increase in gross annual investment since 1926 are estimated from equation 29 (1913-59). The equation predicts a 34 percent total increase in annual investment between 1926 and 1959. Setting the income variable at the 1959 level, other variables at the 1926 level, the equation indicates only a five percent increase in investment. If the income component of output could be included, the increase due to income would be greater than five percent and might be more consistent with the seven percent increase due to income depicted by equation 22 (1926-59). If time is at the 1959 value, other variables at 1926 values, equation 29 depicts only a four percent increase in annual investment. Following the same procedure for the output variable, the equation predicts a 22 percent increase in demand. The sum of the increase attributed to time, four percent, and to output, 22 percent, is 26 percent, and agrees closely with the 27 percent increase associated with time in equation 22, which excluded the output variable. Because time and output are highly correlated, not enough information is available to distinguish the relative influence of each on annual investment. The results indicate that a major portion of the secular increase in annual investment in productive assets is associated with the gradually shifting variables such as time and output rather than with net income. Although these gradual changes are responsible for secular shifts in investment, year to year fluctuations in investment are more closely identified with changes in the volatile net income variable.

Trends and projections

The stock of productive assets increased slowly from 1926 to 1930, then dropped during the depression years of the 1930's (Figure 2). The downward trend was not reversed until 1935. Following that year, the stock of productive assets has demonstrated a continuous, impressive increase. The sharp upward trend showed signs of decreasing in the late postwar period, but 1958 and 1959 observations suggest a linear rather than a declining postwar trend. Equation 28 predicts the actual observations rather well, but inadequately indicates sluggish investment periods such as 1938-39 and 1956-57. The equation indicates that investment stock again will increase in 1960. Under the assumption that net income will remain at the 1955-59 average level until 1965, and that an anticipated eight percent increase in farm output (cf. 73) will be distributed uniformly over the period until 1965, investment stock is projected to be 5.5 percent above the 1960 predicted level by the end of 1965. Thus, the upward trend in stock is projected to continue to 1965 under the above assumptions

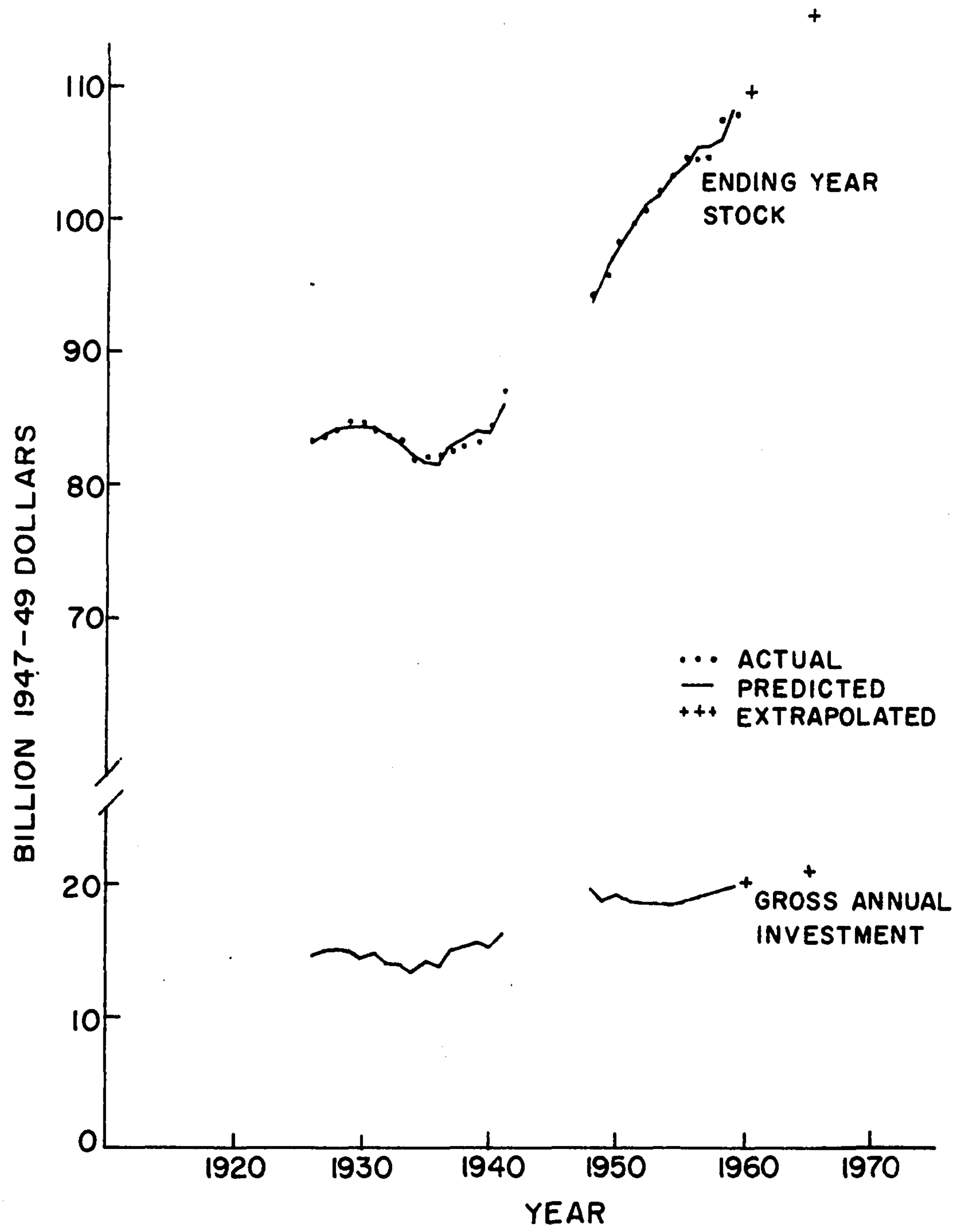

Figure 2. Trends in ending year stock S_p and gross annual investment Q_p in productive assets (actual values of S_p are shown from 1926 to 1959; predicted or projected values of S_p and Q_p from 1926 to 1965 based on equation 28)

according to equation 28.

Gross annual investment is predicted from equation 28, assuming it is model J and employing the prediction relationship indicated by equation 21. Gross annual investment has been remarkably stable over the entire period. Except for troughs in investment in the mid 1930's and 1950's, the equation indicates that annual investment did not fluctuate widely even between prewar and postwar years. Except for the early 1930's, annual investment was greater than replacement requirements, and net additions were made to total stock. Comparing Figures 1 and 2, the lack of volatility in investment in productive assets is notable. One important reason why investment in buildings and machinery is more sensitive to economic conditions than investment in productive assets is the presence of farm produced durables in the latter. Because the reservation price for many farm resources such as land is low, even if market prices are relatively unfavorable, there may be a few alternative uses for these "fixed" resources than to produce additional productive assets for use in later years when prices are favorable. In some instances, "productive" livestock and feed inventories are not held for current or even future production, but are held strictly for direct future sales. Conceptually, these holdings should not be classified as productive assets. However, techniques used to ascertain the quantities of assets are sometimes inadequate to distinguish the true intent or purpose in holding farm inventories.

Based on the same assumptions used to project S_p to 1965, annual investment Q_p is projected to be five percent above the 1960 predicted quantity by 1965. Unfortunately, adequate actual observations were not available to check the predictive ability of equation 28 from 1926 to 1959. The depreciation rate appears to be unusually high, and the estimated level of gross investment may contain an upward bias. It is hoped that the equation predicts the changes somewhat more accurately than the level of annual investment.

Summary of Empirical Results

Farm investment behavior for two aggregate categories of investment (a) the productive portion of building improvements and farm machinery and (b) all farm productive assets are investigated in Chapter 9. The marginal propensity to invest out of net income (as defined in this study) is 0.2 for the first category and 0.3 for the second category of investment. Since more items are included in the second category, all productive assets, it is expected that the marginal propensity to invest would be greater.

Several important implications stem from these results. If farmers are living at subsistence levels as in many underdeveloped areas of the world, the entire net income must be consumed and internal investment cannot occur. External credit agencies must be an important source of investment funds where the marginal propensity to consume is one. Further, improved farming methods and adoption of new technology can play an important role in raising net incomes to levels such that the entire earnings are not consumed by the household. Paradoxically, agriculture must cross the threshold above subsistence before it can begin to grow and prosper from internal investment.

The rather high propensity of American farmers to invest is a reflection of the internal production and market structure that permitted a surplus of income above consumption requirements. But the "savings ethic" of American farmers also has been an important element in the investment process. In some societies it is likely that, given the same income, farmers would have consumed the amount that American farmers invested. In areas where the marginal propensity to invest is very low because of cultural backgrounds, a structure of agriculture featuring individual decisions and initiative such as found in America may not give the desired rate of growth even under favorable income conditions. It is not always desirable to encourage the type of investment included above, of course. In some underdeveloped countries where labor is abundant (the marginal product of labor in agriculture or industry is near zero) and capital is very scarce, encouragement of investment in modern labor saving farm machinery would be incompatible with optimum resource allocation and use of investment funds. Funds would be used more profitably in improving farm management and technology, and in purchasing additional fertilizer and irrigation facilities to increase output. The optimum focus and extent of investment is a function of the stage of development, underlying resource base and goals of society.

The empirical analysis indicates that the elasticity of investment stock S_I with respect to own price P_I is approximately -0.1 in the short run (one or two years) and -0.7 in the long run (over 20 years). The elasticity of S_I with respect to P_R is 0.1 in the short run (one to two years), 0.2 in the intermediate run (three to four years) and 2.0 in the long run (over 20 years). The elasticity of investment stock in productive assets S_p with respect to P_R is estimated to be 0.04 in the short run (one or two years), 0.07 in the intermediate run (three or four years) and 1.0 in the long run (over 20 years). Some interesting patterns in the elasticities are apparent. As expected, the price elasticities of productive assets S_p are consistently lower than those of machinery and improvements S_I. Because of the nature of the production process in agriculture, livestock inventories cannot be readily increased, and some components of real estate inputs are highly restricted. Stock is highly price inelastic in the short run. In the long run, stock is very responsive to price changes according to the analysis. The implication is that government policies and other influences on farm product prices have little influence on stock and consequently on output (through S_p) in the short run. The influence on stock can be sizeable in the long run, however. Whether the increase in stock increases output depends on the elasticity of production. It is well to note that the complete "long run" is never realized because prices are continually changing and because technological and other structural changes obscure the price effects.

Although stock is not sensitive to price changes in the short run, annual investment is highly responsive. For example, the elasticity of Q_I with respect to P_R is approximately 1.0 in the short run (one or two years) and more than 2.0 in the long run (three or four years). This sensitivity of annual investment to prices is a potential source of business fluctuations, but the effect is dampened or cushioned by the remaining large private economic sector and by government spending.

The analysis indicates that gradually shifting influences such as improved technology, managerial ability, and opportunities to substitute machinery for labor primarily have been responsible for the 105 percent rise in Q_I and estimated 34 to 42 percent rise in Q_p from 1926 to 1959.

Projections based on least squares equations are made to 1965. Assuming net farm income will remain at the 1955-59 level and the relative price of investment items in Q_I will increase ten percent by 1965, equations 4 and 12 indicate Q_I will be approximately nine percent above the predicted 1960 level by 1965. Assuming net income will be at the 1955-59 level in 1965, equation 28 indicates annual investment in productive assets Q_p will be five percent above the predicted 1960 quantity in 1965. Under the stated assumptions, stocks S_I and S_p are predicted to grow five and 5.5 percent respectively above predicted 1960 levels by 1965. Under the stated assumptions, the agricultural plant is expected to grow through 1965. Problems of capital accumulation for beginning farmers, large overhead costs, pressures for labor movement out of agriculture due to adoption of labor saving machinery, and other structural changes accompanying increased capitalization of agriculture will remain. But more important, society reaps the benefits of higher real income and farmers obtain the advantages of less hand labor and drudgery and other conveniences of a highly mechanized agriculture.

CHAPTER 10: THE MARKET STRUCTURE OF FAMILY AND HIRED FARM LABOR

The total number of agricultural workers declined from 13.6 million in 1916 to 7.4 million in 1959. Since 1926, the number of all agricultural workers has declined at an average compound rate of 1.7 percent per year. Despite the rapid out-movement of workers, the per capita ratio of farm to non-farm income remains low. The ratio was 0.43 in 1926, and was 0.41 in 1959 (121). The relative per worker income in agriculture has not improved. Yet economic theory postulates that adjustments should occur until returns to a given resource are equal in all comparable uses in a free market economy.

Answers to a number of fundamental questions depend heavily on the nature of the labor market in agriculture. Whether a return to an agriculture free of government controls will eventually raise farm income per worker depends on the responsiveness of farm workers to a fall in relative income. Whether a government policy to raise farm income perpetuates the farm problem by retarding needed labor adjustments also depends on the nature of the labor function in agriculture. How farm labor mobility is influenced by non-farm variables such as national unemployment and the non-farm wage rate is one of the basic questions asked by individuals concerned with agricultural adjustment. The interrelationships of policies affecting national employment and farm labor mobility cannot be accurately judged without gaging the magnitude of parameters in the farm labor function. In this chapter, we attempt to derive estimates of quantities which will aid in answering these and other fundamental questions about the agricultural labor markets.

Two categories of farm labor (a) hired and (b) family are considered in this chapter. Principal emphasis is placed on family labor because: (a) it comprised a major portion, 75 percent, of the total farm labor force from 1955 to 1959, (b) knowledge of family labor mobility is an important element in appraising alternative policy instruments such as free prices, or subsidies to achieve the target of parity farm income per worker, and (c) family labor has received little attention in previous quantitative studies. Family labor functions are specified and estimated by single equation least squares. The results provide the basis for inferences about the relative influence (elasticities) of variables on labor mobility and of historical sources and projected changes in the number of family laborers engaged in agriculture. The demand function for hired labor is estimated by least squares. In addition, demand and supply functions for hired labor are estimated by limited information simultaneous equations. Inferences are made from these equations about the relative influence of price and other variables on the number of hired workers in agriculture, and projections are made to 1965.

Price and Quantity Ratios

Before presenting the more complex statistical analysis of labor markets, we present graphically some of the major substitutions taking place between labor and other major farm inputs. The graphic presentation provides a useful historical perspective of changes occurring in the resource structure and also illustrates some of the major substitutions not readily apparent from more complex statistical functions.

Economic theory postulates that the marginal rate of substitution (and marginal products) be equated with the relevant price ratios to maximize profits. In the absence of technological changes or other complexities, an increase in the relative price of labor will be associated with a decrease in the quantity employed. In Figures 1 to 4, it is possible to observe if the substitutions are consistent with price relationships. It is well to keep in mind that complex interrelationships may escape the two dimensional setting.

Figure 1 shows indices of the ratios: (a) the number of hired and family workers Q_{TL} to operating inputs Q_O', and (b) the wage rate of hired farm labor P_{HL} to the price of operating inputs P_O from 1910 to 1959. The underlying assumption is that P_{HL} is the relevant decision variable for family as well as hired labor. Price and quantity ratios remained quite stable from 1910 to World War I. Except for the depression, and early post World War II period, P_{HL} increased

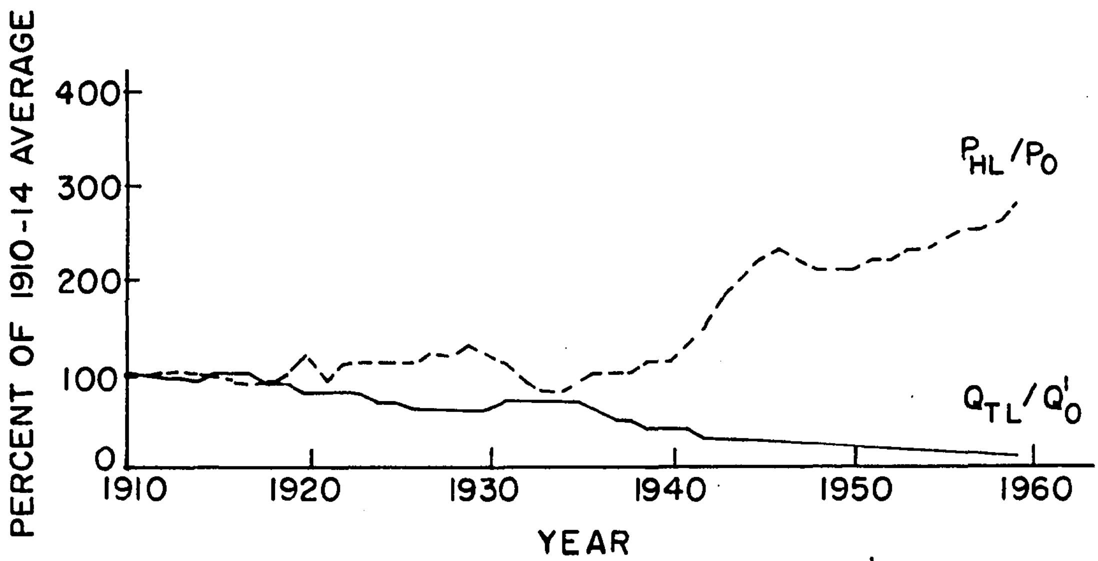

Figure 1. Indices of the ratio P_{HL}/P_O and Q_{TL}/Q'_O from 1910 to 1959; 1910-14 = 100 (P_{HL} is the farm wage rate, Q_{TL} the number of all workers employed in agriculture; P_O and Q'_O are operating input price and quantity)

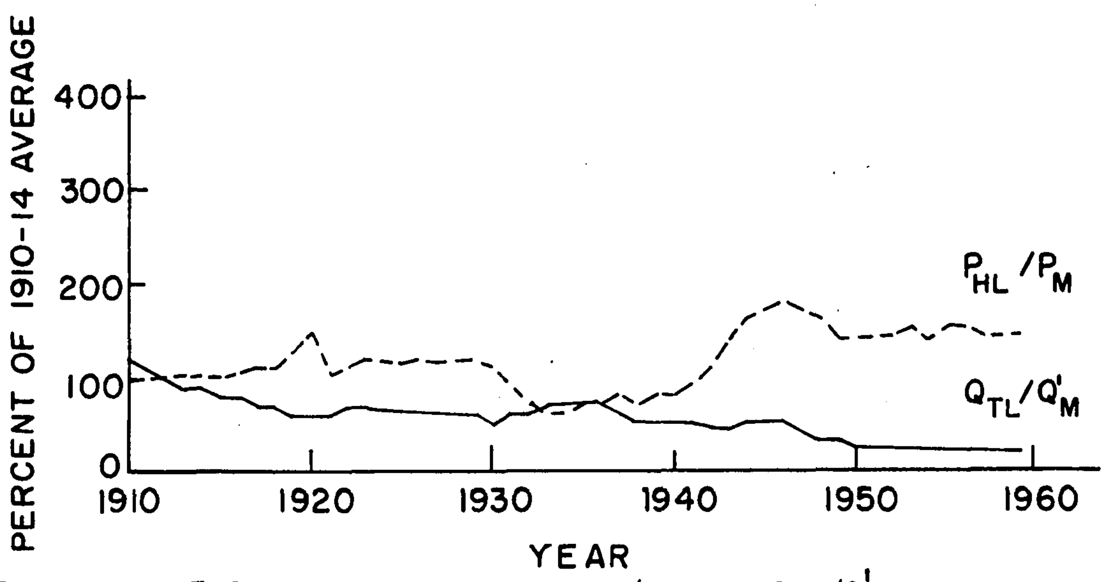

Figure 2. Indices of the ratio P_{HL}/P_M and Q_{TL}/Q'_M from 1910 to 1959; 1910-14 = 100 (P_{HL} is the farm wage rate, Q_{TL} the number of all workers employed in agriculture; P_M and Q'_M are the farm machinery price and quantity)

relative to P_O since 1921. The increase in the price of labor resulted in the substitution of operating inputs for total labor. The results are consistent with rational economic behavior.

Indices of the ratios of: (a) total employment in agriculture Q_{TL} to machinery inputs Q_M' and (b) the farm wage P_{HL} to machinery price P_M are illustrated in Figure 2. Machinery inputs are valued as the services required to maintain the input at current levels. The direction of trends in prices and quantities in Figures 1 and 2 are similar. The price ratio P_{HL}/P_M has increased less than the relative prices of other major inputs, but the substitution is large. The extent of substitution appears inconsistent with price movements in some periods such as 1910 to 1916 and 1946 to 1950. These and other inconsistencies partially are explained by technological changes in machinery which decrease the real price, but are not reflected in the price coefficients. It is notable that the price and quantity ratios have remained quite stable since 1950 in Figure 2.

Figure 3 depicts indices of the ratios: (a) Q_{TL} to real estate inputs (services) Q_{RE}, and (b) P_{HL} to per acre land values P_{RE} from 1910 to 1959. A gradual substitution of land for labor is indicated by Figure 3, but the rate of substitution seems unresponsive to relative prices P_{HL}/P_{RE}. A possible explanation is that land prices are a residual relation-

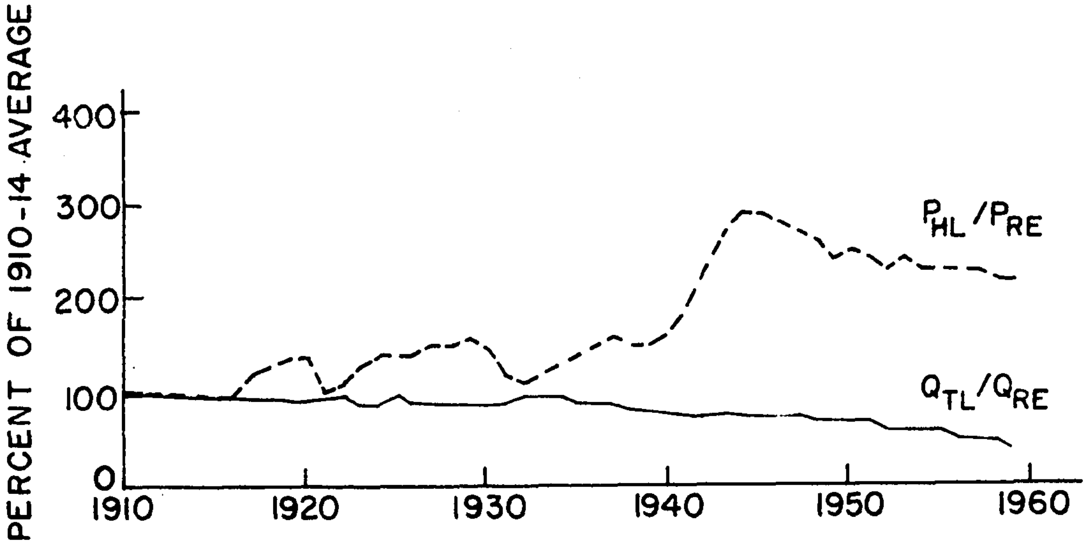

Figure 3. Indices of the ratio P_{HL}/P_{RE} and Q_{TL}/Q_{RE} from 1910 to 1959; 1910-14 = 100 (P_{HL} is the farm wage rate, Q_{TL} the number of all workers employed in agriculture; P_{RE} is the land price per acre and Q_{RE} is the input of real estate)

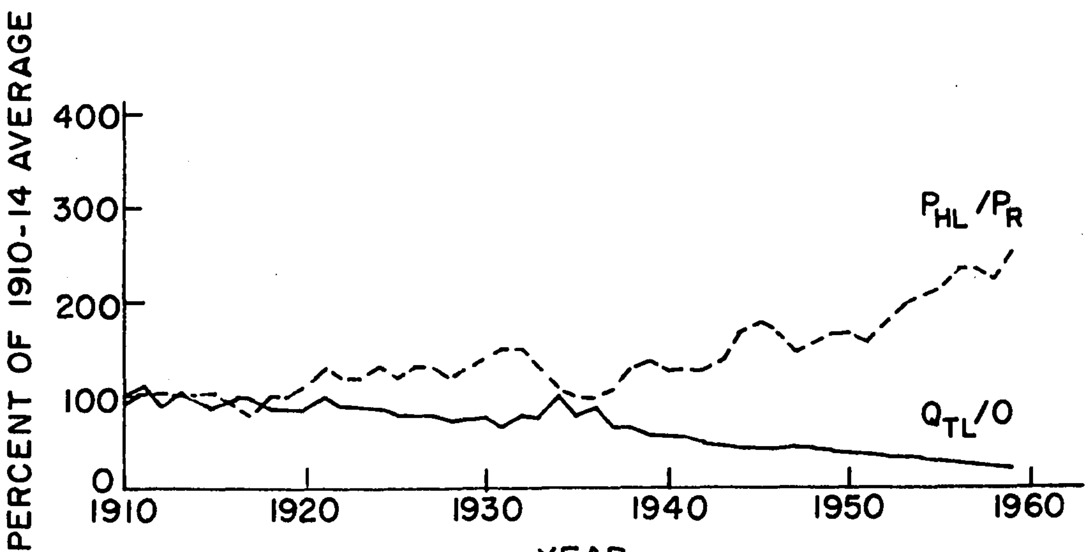

Figure 4. Indices of the ratios P_{HL}/P_R and Q_{TL}/O from 1910 to 1959; 1910-14 = 100 (P_{HL} is the farm wage rate, Q_{TL} the number of all workers employed in agriculture; P_R is prices received by farmers for crops and livestock, O is total farm output)

ship reflecting the general profitability of farming and is not a relevant decision variable. The ratio of labor to land is determined to a greater extent by more basic price ratios such as depicted in Figures 1 and 2 and by technological forces.

Indices of the ratios: (a) Q_{TL} to farm output O and (b) P_{HL} to prices received by farmers for crops and livestock P_R are illustrated in Figure 4. In the absence of overriding improvement in the quality of farm labor, one would expect a decrease in labor inputs to equate the marginal product with the rising price ratio. Figure 4 indicates that this type of adjustment has occurred in agriculture. The ratio of labor input to farm output (and all inputs) has declined at a particularly rapid rate since the mid 1930's. Some interruptions in the changing relative price of labor are apparent, but a general upward tendency is apparent in the same periods.

Figures 1 to 4 indicate that adjustments of resources are consistent with a movement toward economic efficiency. The more complex influences associated with the changing structure of the labor input are examined in the following sections.

Family Labor Functions

Some possible explanations for the discrepancy between farm and non-farm labor returns are: (a) that the existing ratio of farm and non-farm incomes represents an equilibrium; that relative incomes are equal because psychic income from the farm way of life is very great, (b) the ratio of returns represents an equilibrium, equal returns for equal skills, because worker skills in agriculture are low, (c) that unionization of urban workers has reduced the mobility of farm workers and has perpetuated the disequilibrium income problem, (d) that mobility between regions is low and that no serious disequilibrium exists between farm and non-farm earnings in a given region, (e) farmers are unaware of higher earning potential in alternative employments, (f) that farmers are responsive to wage differentials but that unemployment in the urban sector has hindered farm labor mobility, and (g) that farmers are responsive to wage (income) differentials but the responsiveness (elasticity) has not been high enough to cope with changes in farm structure. These changes in farm structure include output increasing (income decreasing) farm investment and technology.

Studies by D. Gale Johnson (65, 66, 67, 79, 70) provide support for rejecting hypotheses (a) to (d). He states that it would be necessary for per capita income of the farm population to be about 60 to 70 percent of the per capita income of the non-farm population to have comparable real incomes (66, 67). While it is reasonable to expect that in equilibrium some difference would exist between farm and non-farm incomes due to psychic returns in the farm sector, the current discrepancy is too great to be explained by hypothesis (a). Johnson (65) and Bishop (13) provide data to reject the second hypothesis that skill capacities of rural workers is low. Based on actual earnings of farm migrants to urban areas and of urban non-migrants, they conclude that the average laborer employed in agriculture has a labor capacity approximately 90 percent of the labor capacity of urban and rural non-farm populations for similar age and sex distributions. It is notable that differences in skills and earning capacities between farm migrants and non-farm workers in urban areas tends to diminish with additional experience of farm workers on non-farm jobs. Johnson's (69) work also indicates that hypotheses (c) and (d) do not explain the differential in incomes between agriculture and other industries. Unions have not been a serious obstacle to farm labor mobility. Also differentials in income between farm and non-farm sectors are found throughout the country. Sizeable gaps exist between returns from farm and urban employment in all low income farming areas of the country. Also, some mobility exists between sectors, thus hypothesis (d) does not explain the failure of the gap between per capita incomes in agriculture and other industries to narrow.

The principal purpose in this section is to evaluate hypotheses (f) and (g). The hypotheses imply that the responsiveness of family workers to a change in relative earnings is too low to cope with the output increasing (income depressing) technology and capital formation, particularly when unemployment is high. Quantitative measures of the influences of some of these relevant variables are necessary to evaluate the hypotheses.

Specification of a family labor function

Before specifying the family labor function as conceived in this study, it is well to consider previous specifications of similar functions. Despite the importance of family labor in determining per capita income and labor efficiency in agriculture, few quantitative studies have dealt with the family labor function. S. Johnson (74) specified the number of family workers in agriculture as a function of the farm wage rate P_{HL}, the value of farm machinery, the ratio of farm prices received to prices paid for production items, time, and a lagged dependent variable. Depending on the period estimated, the magnitude and signs of the coefficients differed considerably (74, p. 92). In 1961, Sjaastad (107) published estimates from a regression of a two year moving average of net off-farm migration on the ratio of per capita farm to non-farm incomes, and the percent of national unemployment. The size and sign of the coefficients varied markedly, depending on the period being estimated. Bishop (11) regressed the rate of migration on the ratio of farm to non-farm earnings and the percent of the labor force unemployed in the economy. Again, the magnitude and significance of the coefficients were highly sensitive to the specification and time period considered.

In this section, we attempt to develop a flexible model of labor mobility accommodating a fluctuating income and employment structure. The purpose is to obtain reliable estimates of the influence of unemployment and other factors on labor mobility from a function fitted to data extending over periods of heterogeneous employment and wage structures.

A single equation expressing the number of family workers as a function of earnings, unemployment and other variables appears satisfactory. Some justification for the single function is provided by the fact that the decisions to supply more manual labor or management in response to a favorable derived demand are made by the same individual. Too, the number of family workers remaining in agriculture is assumed to be a function of <u>predetermined</u> past income, financial position, machinery investment, and of exogenous unemployment and non-farm income variables.

Some studies (74) have assumed that the hired farm wage rate, prices paid, and prices received by farmers are the relevant family labor decision variables. In this study, residual farm income is used as the measure of the "price" of family labor. The logic is that family labor is not an out-of-pocket cost and, hence, market prices are not necessarily relevant. Whether the family worker stays on the farm is assumed to be a function of the residual income which remains to pay living expenses after production costs are paid. Although prices are unfavorable, this residual still may be sizeable because of improved farming efficiency and management, or good weather. To consider the decision of a family worker to remain in agriculture as a function of farm prices received relative to the price of hired labor would ignore the increased residual to family labor growing out of increased farming efficiency and other structural changes associated with improved entrepreneurial skills. There are also definite statistical advantages from summarizing the many price and efficiency aspects into the single variable.

We specify the number of family workers employed in agriculture Q_{FL} as a function of the ratio of income per factory worker to income per farm worker Y_R, the national unemployment rate U, the farm equity ratio E, forced farm sales F, government programs G, machinery investment S_M and slowly changing influences T. The form and logic of the specification needs additional explanation.

The usual statistical model is a simple linear function, for example,

(1) $$Q_{FLt} = a - bY_{Rt-1} + c\,U_{t-1} + d\,X$$

where X represents variables other than income and unemployment influencing Q_{FL}. The negative coefficient of Y_R indicates that as non-farm income rises relative to farm income, Q_{FL} will decrease as family workers take urban employment. An important aspect of labor mobility which creates unstable coefficients in linear equations such as above is the interaction between U and Y_{Rt-1}. The rate b at which a given income ratio moves workers off farms is a function of the unemployment rate. To account for this structure, an interaction variable Y_R (1-U) is added to equation 1 to form equation 2.

(2) $Q_{FLt} = a - b\, Y_{Rt-1} + c\, U_{t-1} + d\, X - e\left[Y_R(1-U)\right]_{t-1}$.

Combining the two terms containing income, the coefficient of Y_R is $-b -e\,(1-U)$ and obviously is a function of the level of unemployment.

Equation 2 is modified slightly to conform to certain a priori considerations. There is some doubt whether unemployment U shifts the level of family labor of itself, irrespective of income and other influences. To correct for this, the variable U_{t-1} is omitted. Second, it is likely that if U reaches some level, the coefficient of relative income becomes zero. The implication is that when national employment reaches some critical level V, a low relative income in agriculture no longer is effective in adjusting employment to equilibrium levels. Under these circumstances, average incomes are not a useful economic indicator. At the <u>margin</u>,

Y_R is zero because the marginal non-farm income is zero for the unemployed factory worker (assuming no unemployment compensation). If the signs of the coefficients are as indicated in equation 2, the coefficient of Y_R approaches -b as U approaches one. This critical value is too high, and equation 2 is modified in two ways to accommodate a lower value. The first is to assign different values of V in the interaction term. The equation is

$$(3) \qquad Q_{FLt} = a - b\left[Y_R(1 - U/V)\right]_{t-1} + d\ X\ .$$

It is apparent that when U equals V, b equals zero. The variable within brackets may be constructed for several values of V until one is found by trial and error giving the highest R^2. The variable is constructed to equal zero when U is greater than the assigned value of V. The assumption is that b may be negative or zero but not positive.

If we allow b to be positive or negative, the trial and error method for finding V in equation 3 may be replaced by a non-iterative scheme. The case for a positive coefficient b when U is larger than V is supported by the growth in numbers of agricultural workers during the depression. If the necessary statistical assumptions also are met, the following model will also give the best linear unbiased estimate of V. The model is formed by multiplying the terms within the brackets of equation 3 by b. The result is

$$(4) \qquad Q_{FLt} = a - b\ Y_{Rt-1} + \frac{b}{V}(U\ Y_R)_{t-1} + d\ X\ .$$

It is apparent that the critical unemployment level V at which relative income no longer is effective in drawing workers from agriculture is readily computed from the coefficient of UY_R. Equation 4 does not restrict the value of b -- the coefficient becomes positive when U is greater than V. This conforms with historical experience. The greatest potential influence of Y_R on Q_{FL} is indicated by b. That is, the coefficient of Y_R is the maximum negative value b only when unemployment is zero. The logic of the model of income and unemployment depicted in equation 4 is appealing and is the foundation for several fitted equations in the empirical section.[1]

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[1]Other, non-linear assumptions about the relationship between unemployment and relative incomes may be appropriate. One is to assume a model of the form

(a) $$Q_{FL} = a\ Y_R^{-b(1-U/V)}\ X^c\ .$$

It may be estimated by least squares as a linear function

(b) $$\log Q_{FL} = \log a - b \log Y_R + \frac{b}{V}(U \log Y_R) + c \log X.$$

Another suggested model is

(c) $$Q_{FL} = a - b\ Y_R\ (1 - U^2/V) + c\ X$$

and would be estimated by ordinary least squares as

(d) $$Q_{FL} = a - b\ Y_R + \frac{b}{V}(U^2\ Y_R) + c\ X.$$

The variables

The "X" variables in equation 4 need further explanation. These variables are investment in farm machinery S_M, the equity ratio E, percentage of forced (bankruptcy) sales F, government programs G and slowly changing influences T. If farmers are in a favorable financial position because of inflated land or other values or because past income has been greater than expenses, it is reflected in the ratio of proprietors' equity to liability. E is a measure of long term financial success and ability to withstand the vicissitudes of short run income fluctuations. If E is high, farmers may be able to withstand short run income reverses by utilizing past financial reserves.

Investment in machinery is to some extent output and cost increasing for a given number of workers. Due to the inelastic demand for farm products, these influences of machinery are reflected in residual farm income. Some may argue that machinery investment need not be specified separately in the labor function because the labor saving feature does not of itself reduce family employment -- workers need only work fewer hours and receive the same income. There exists an important indirect reason for specifying an investment effect other than reflected in farm income. One of the chief barriers to persons wishing to enter farming is high capital requirements. Although farm income is favorable, some workers will migrate because of high capital requirements, or because they are not needed on highly mechanized farms.

The following variables undoubtedly have influenced family labor mobility, but cannot be specified separately in the labor function. The slowly changing time variable T indicates some of these influences. Improved education has increased the mobility of the farm population. With improved skills and removal of cultural barriers through education, migrants adjust more readily to a changing environment. Barriers to mobility also have declined gradually with better roads, cars, airplanes and other advanced transportation. Changes in communications such as the rise of the movie, radio and television industry have changed value structures and removed some of the impediments to job flexibility. The influence of economies of scale and consequent pressures for larger and fewer farms also may be reflected in the time variable.

When farm incomes become very low, the "smoothly" functioning labor market breaks down as farmers become bankrupt. To accommodate this changing structure, a variable indicating the percent of forced sales is included in the labor function. The family farm operator who has lost his farm may become a hired farm laborer if he cannot find employment in a depressed urban economy.

Government policies which influence farm income are reflected in Y_R. But other indirect influences of legislation may be specified separately. Land retirement policies may have a direct effect not shown by Y_R, and are indicated by a separate variable G.

Finally, if adjustments to relative income, machinery investment and other explanatory variables are made slowly, the lagged employment variable Q_{FLt-1} may be specified in the labor function to estimate the adjustment coefficient (cf. model F, Chapter 7).

Some may contend that an improved farm financial position indicated by a low value of Y_R or a high value of E facilitates labor mobility by providing capital for moving. The fact that outmovement of family laborers has been rapid from low income areas provides a sufficient basis for rejecting this hypothesis. This does not preclude the hypothesis that favorable agricultural earnings reduce the number of agricultural workers in the long run by providing funds for labor saving farm mechanization.

The variables in the family labor function are defined specifically as follows:

Q_{FLt} The dependent variable is the number of family workers employed in agriculture during the current year, measured in 10 thousands (30, 118).

Y_{Rt-1} An index of the ratio of the average annual wage per employed factory worker to the residual farm income per family worker in agriculture in the past year

(118, 121). Residual farm income is gross farm income, including government payments and non-money income, less production expenses including hired labor. The index is expressed as a percent of the 1947-49 average.

U_{t-1} The percentage of the national labor force unemployed during the past year, unadjusted for seasonal variation (30). When specified with income as UY_R, the unemployment variable is a proportion rather than a percent.

E_{t-1} The past year ratio of proprietors' equity to liabilities in agriculture (4, 123).

F_t The percentage of farm sales forced through bankruptcy in the current year (118).

G_t An index of government policies. Years when acreage allotments or production controls are in force are given the value -1. Years when farm prices are supported are assigned values of +1. If supports are fixed, an additional +1 is added. The values are summed to form the index G (3, 34).

S_{Mt} The stock of all productive farm machinery on farms January 1 of the current year (4, 123). The variable is in millions of 1947-49 dollars.

T Time, an index composed of the last two digits of the current year.

All the above variables are annual data for the U.S. from 1926 to 1959, omitting 1942 to 1945. Some of the variables were not available prior to this period. While there would be obvious advantages in analyzing the labor function for various segments of the 1926-59 period, the data are not considered adequate for such refinements.

Family labor equations estimated by least squares

The six explanatory variables in equation 5, Table 1, explain a large proportion of the annual variation in the quantity of family labor employed on farms. Two variables, F and G, contribute little to the explanation, however. The results indicate that there has been an insignificant direct effect of government programs G and forced (bankruptcy) sales F on labor mobility not reflected by other variables such as Y_R and E. In equation 6, the beginning year stock of machinery S_M is substituted for these variables. The standard error is twice the coefficient of the machinery variable. For this reason, S_M is excluded in equation 7. The four independent variables in equation 7 explain 98 percent of the variation about the mean of Q_{FL}. The coefficient of Y_R is significant at the 95 percent probability level, the other coefficients are significant at the 99 percent level. All coefficients display the expected signs. The test for autocorrelation in the equation is inconclusive.

If E is omitted and F and G are included as in equation 8, the coefficient of G is positive and significant. If taken

Table 1. Functions for family labor Q_{FL} estimated by least squares with annua
1942 to 1945; coefficients, standard errors (in parenthesis) and rel

Equation	R^2 and $\bar{R}^2$	d' [b]	Constant	Y_R t	UY_R t	Y_R t-1	UY_R t-1	E t-1
5	0.979 0.974	1.16	1344			-0.50 (0.25)	3.32 (0.67)	19.31 (5.03)
6	0.979 0.974	1.10	1367			-0.40 (0.31)	3.30 (0.83)	16.01 (2.75)
7	0.978 0.975	1.14	1385			-0.50 (0.24)	3.60 (0.54)	16.07 (2.70)
8	0.966 0.959	0.86	1469			-0.75 (0.30)	4.33 (0.77)	
9	0.983 0.981	1.10	1455	-1.16 (0.19)	4.69 (0.47)			11.74 (2.12)
10[c]	0.990 0.988	--[c]	--[c]	-0.56 (0.18)	2.22 (0.60)			1.79 (2.66)
11	0.989 0.987	1.40	324			0.25 (0.23)	0.30 (0.78)	7.90 (2.58)
12	0.993 0.991	1.68	671	-0.48 (0.18)	2.29 (0.52)			7.43 (1.61)

[a]Sources and composition of the dependent variable Q_{FL} and of the indicate
text. All equations are linear in original values.

[b]The Durbin-Watson autocorrelation statistic d'.

[c]Estimated by least squares with a first order autoregressive transformati
coefficient was estimated to be 0.92; the standard error 0.09. The Durbin-Wats
constant terms were not computed for the autoregressive equation.

: Q_{FL} estimated by least squares with annual data from 1926 to 1959, excluding
;, standard errors (in parenthesis) and related statistics are included[a]

Y_R t	UY_R t	Y_R t-1	UY_R t-1	E t-1	S_M t	F t	G t	T	Q_{FL} t-1
		-0.50	3.32	19.31		0.71	-0.47	-15.27	
		(0.25)	(0.67)	(5.03)		(0.99)	(0.94)	(1.08)	
		-0.40	3.30	16.01	-0.0022			-14.97	
		(0.31)	(0.83)	(2.75)	(0.0046)			(1.34)	
		-0.50	3.60	16.07				-15.52	
		(0.24)	(0.54)	(2.70)				(0.70)	
		-0.75	4.33			-1.19	2.13	-14.04	
		(0.30)	(0.77)			(1.08)	(0.82)	(1.30)	
-1.16	4.69			11.74				-14.63	
(0.19)	(0.47)			(2.12)				(0.60)	
-0.56	2.22			1.79				-1.41	
(0.18)	(0.60)			(2.66)				(1.19)	
		0.25	0.30	7.90				-5.13	0.74
		(0.23)	(0.78)	(2.58)				(2.19)	(0.15)
-0.48	2.29			7.43				-7.43	0.54
(0.18)	(0.52)			(1.61)				(1.33)	(0.10)

dependent variable Q_{FL} and of the indicated independent variables are discussed in the
riginal values.

ion statistic d'.

h a first order autoregressive transformation. The first order autoregressive
; the standard error 0.09. The Durbin-Watson autocorrelation statistic and
the autoregressive equation.

seriously, the inference is that government programs significantly have influenced family labor mobility. The inconsistency of the results in equations 5 and 4 and the crude formulation of the variable G suggest that the extent of the direct influence of government programs on labor mobility cannot be determined from the equations in Table 1.

When current rather than past income and employment variables are included in the labor function, the magnitude and significance of the coefficients of Y_R and UY_R are increased. The R^2 is greater in equation 9 than in equation 7. Statistically, equation 9 is preferable, but logically equation 7 with lagged variables is desirable. It is expected that at least a one year lag is required for farmers to adjust to a change in relative incomes.

The relatively low values of d' casts doubt about the randomness of the residuals in equation 9 and previous equations. For this reason equation 9 is estimated assuming the residuals follow a first order autoregressive scheme.[2] Auto-

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[2]The assumption is that the residuals are formed by a Markov process, i.e.

(a) $u_t = A\, u_{t-1} + e_t$

where u_t is the current residual and e_t is randomly distributed. In equation 10, the residual is found by an iterative process with a high speed electronic computer, and is

(b) $$u_t = \underset{(0.09)}{0.92}\, u_{t-1} + e_t \,.$$

regressive equation 10 is estimated with the assumption that the current residuals are a linear function of the residuals in the past year plus a random element. The transformation resulted in a first order autoregressive coefficient of 0.92 with a standard error of 0.09. The highly significant coefficient obviously has absorbed the time trend in equation 10. The autoregressive transformation (and time T) essentially is a substitute for other variables which cannot be specified individually in the equation. Whether the secular trend is reflected in the autoregressive scheme or in the time variable itself does not necessarily lead to a different interpretation. Either result is an indication of our inability to specify more exact variables and we can only postulate what influences either represents. Analysis of employment numbers (cf. Figure 5) suggests a strong basis for a time trend not adequately explained by the independent variables. Equation 10 adds little to our knowledge of labor mobility and is more difficult to interpret than other equations in Table 1. Thus, inferences of the nature of family labor mobility in subsequent pages are based on other equations in Table 1.

Equations 11 and 12 are estimated with a distributed lag to allow a gradual adjustment to equilibrium. The results using the current rather than past income and employment variables are more acceptable. Certain considerations suggest that inclusion of the lagged employment variable completes the specification. First the coefficient of the variable is significant and the R^2 is increased. Second, the autoregressive transformation applied to equation 12 (the equation is not included) resulted in a first order coefficient of 0.58 with a standard error of 0.33. The R^2 was not increased by the transformation. A highly insignificant F test for the contribution of the autoregressive transformation to the explanation of employment suggests that introducing the autoregressive scheme only realigned coefficients and did not improve the explanation.[3] The coefficients of income, employment and Q_{FLt-1} remained nearly the same, but the coefficients of E and T were reduced substantially by the autoregressive form of equation 12. A third reason for thinking that addition of Q_{FL} completes the specification is the similarity of the coefficients of Y_R and UY_R in equations 10 and 12. The implication is that the autoregressive scheme "substituted" for Q_{FLt-1} in equation 10. It is not possible to infer from this that the autoregressive transformation always will substitute for an incomplete specification. Even if the short run coefficients of Y_R and UY_R are more accurately measured after the transformation in

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[3]The F test is sometimes useful for estimating the contribution of one or more additional variables when collinearity is high and the standard errors for t tests are highly sensitive to the specification. The procedure for the F test is found in Foote (33).

equation 10, without knowledge of the correct structure, inferences about the long run coefficients would be incorrect. The long run labor function is found by dividing the coefficients in equation 12 by the adjustment coefficient 1 - 0.54 = 0.46. If this is done, it is interesting to observe that the long run coefficients are very similar to the coefficients of equation 9, estimated without the lagged employment variable.

The R^2 is 0.99, the coefficients meaningful and significant -- equation 12 appears to be a useful expression of the family labor function. Some instability is introduced by the high simple correlation ($r = 0.94$) between T and Q_{FLt-1}. Other simple correlations among explanatory variables are less than 0.90 in equation 12.

To help resolve the question of the importance of current and past price and employment variables posed by Table 1, the specification of the family labor function may be modified slightly. Let us assume that decisions to seek alternative employment are based on expected relative income. The expected income is likely to be based primarily on past income because current income is not known until late in the year. If expected income is favorable, the ultimate and final decision to change jobs may depend on <u>current</u> unemployment. This reasoning leads to specification of variables Y_{Rt-1} and U_tY_{Rt-1} in the family labor function. The resulting least squares equation is

$$(13) \quad Q_{FLt} = \underset{}{1407} - \underset{(0.29)}{0.86}\, Y_{Rt-1} + \underset{(0.64)}{4.27}\, (U_t Y_{Rt-1})$$

$$+ \underset{(2.82)}{12.70}\, E_{t-1} - \underset{(0.73)}{14.57}\, T\ .$$

$$R^2 = 0.979 \qquad d' = 1.19$$

In some respects the equation is an improvement over equation 7. The R^2 is slightly higher, the magnitude and significance of the coefficient of Y_{Rt-1} is greater. Also, the degree of autocorrelation, indicated by d', is somewhat less in equation 13. The importance of current and past price variables is not completely resolved, however. To avoid misinterpretation, coefficients of either current or past income and employment variables are labeled "short run".

Table 2 illustrates alternative specifications of the family labor function based on the variables found most useful in Table 1. The importance of unemployment in labor mobility is illustrated forcefully in equation 14. The number of family laborers is specified as a conventional simple linear function of Y_R, U, E and T (cf. equation 1). The coefficient of Y_R is non-significant and the sign is incorrect. Yet the coefficient of determination is larger than for several equations in Table 1. Addition of the interaction term in equation 15 reverses the sign on the coefficient of Y_F, but neither the coefficient of Y_F nor of $Y_F(1-U)$ is significant (cf. equation 2). It is probable that an F test for the joint influence of the two variables containing Y_R would be

Table 2. Alternative functions for family labor Q_{FL} estimated by least squares with excluding 1942 to 1945; coefficients, standard errors (in parenthesis) and

Equation	R^2 and $\bar{R}^2$	d'[b]	Constant	Y_R t	U t-1	$Y_R(1-U)$ t-1	$Y_R(1-3U)$ t-1	$Y_R(1-5U)$ t-1	$Y_R($
14	0.984 0.982	1.07	1285	0.19 (0.14)	6.40 (0.76)				
15	0.986 0.983	1.04	1212	-1.83 (1.45)	10.49 (3.01)	2.56 (1.82)			
16	0.916 0.907	0.25	1295			0.68 (0.38)			
17	0.954 0.949	0.78	1517				-1.34 (0.26)		
18	0.975 0.972	0.79	1443					-0.95 (0.11)	
19	0.970 0.966	0.58	1430						
20	0.993 0.992	1.36	750						-0. (0.

[a]Sources and composition of the dependent variable Q_{FL} and of the indicated indep text. All equations are linear in original values.

[b]The Durbin-Watson autocorrelation statistic d'.

r Q_{FL} estimated by least squares with annual data from 1926 to 1959,
standard errors (in parenthesis) and related statistics are included[a]

l	$Y_R(1-U)$ t-1	$Y_R(1-3U)$ t-1	$Y_R(1-5U)$ t-1	$Y_R(1-5U)$ t	$Y_R(1-7U)$ t-1	E t-1	T	Q_{FL} t-1
40						22.43	-16.52	
76)						(2.31)	(0.60)	
49	2.56					16.69	-17.19	
01)	(1.82)					(3.79)	(0.76)	
	0.68					13.99	-15.56	
	(0.38)					(5.20)	(11.36)	
		-1.34				6.84	-14.47	
		(0.26)				(2.95)	(0.97)	
			-0.95			13.35	-15.24	
			(0.11)			(2.27)	(0.71)	
					-0.90	14.50	-15.47	
					(0.12)	(2.55)	(0.79)	
				-0.59		8.19	-8.20	0.49
				(0.11)		(1.65)	(1.38)	(0.10)

'ariable Q_{FL} and of the indicated independent variables are discussed in the
.es.

.c d'.

significant. Thus, equation 15 does not necessarily lead us to accept the hypothesis that relative incomes are unimportant in determining the level of family employment.

Equations 16 to 19 are included to illustrate the results of using several critical unemployment values V (cf. equation 3). The income-employment variable Y_F (1-U/V) is constructed to equal zero when U is greater than V. For convenience the critical value is given as a reciprocal in Table 2. That is, for Y_R(1-3U), V = 0.33; for Y_R(1-5U), V = 0.20; and for Y_R(1-7U), V = 0.14. When V = 1.00 in equation 16, the coefficient of the income-employment variable is insignificant, the R^2 is relatively low and autocorrelation in the residuals is highly significant. As V is decreased to 0.20 the R^2 increases, the degree of autocorrelation in the residuals declines and the significance of the coefficient of the income-employment variable increases appreciably. The results indicate that V approximately is 20 percent unemployment.

Equation 20 estimated with a distributed lag, and assuming V equals 0.20, explains 0.99 percent of the annual variation about the mean of Q_{FL}. All coefficients have the expected signs and are highly significant. The estimated adjustment coefficient 0.5 is the same as that estimated in equation 12, Table 1. The distributed lag model appears to be a useful form of the family labor function. It may be noted that the long run coefficients of E and T, found by dividing the short run coefficients by the adjustment rate 0.5 in equations 12 and 20, are nearly equal to the coefficients of E and T in equations 5 to 9 and 14 to 19.

Income elasticities

The elasticities of family labor numbers with respect to relative incomes are illustrated in Table 3. The results indicate that the short run (one or two years) response to relative incomes is low and is sensitive to the level of unemployment. The maximum short run elasticity (zero unemployment) probably is no greater than -0.1 according to Table 3. The implication is that a 10 percent decline in farm income relative to income of factory workers could decrease the number of family workers up to one percent in the short run. But if unemployment were 15 to 20 percent, a 10 percent decline in relative farm income would have no effect on the number of family workers in agriculture. Thus, the short run response of Q_{FL} to relative incomes is low when national unemployment is low and is negligible when unemployment reaches 15 to 20 percent according to Table 3.

The long run response of family workers to changes in relative incomes is considerably greater than the short run response. In the long run, the farmers' financial situation, indicated by the equity ratio E, deteriorates with a low farm income. The result is that the long run elasticity with

Table 3. Elasticities of family labor Q_{FL} with respect to farm income per family wo per worker Y_{NF} estimated at the mean from selected equations in Tables 1 a

Unemployment (percent)	Equation 7		Equation 12		
	Short run (1-2 years)	Long run (4-6 Years)	Short run (1-2 years)	Long run (4-6 years)	
	Y_R[a]	Y_F'[b]	Y_R[a]	Y_{NF}[c]	Y_F'[d]
0	-0.089	--	-0.087	-0.189	--
5	-0.057	0.25	-0.067	-0.144	0.34
10	-0.024	0.22	-0.046	-0.099	0.30
15	0.008	--	-0.025	-0.054	--
20	0.041	--	0.004	0.008	--
25	0.073	--	0.017	0.037	--
1926-59 average (9 percent)	-0.031	0.23	-0.050	-0.108	0.31
1946-59 average (4 percent)	-0.063	0.26	-0.071	-0.153	0.35

[a]The short run elasticities with respect to Y_R. Since $Y_R = Y_{NL}/Y_F'$, the short r to Y_R, Y_{NL} and $-Y_F'$ are equal.

[b]The long run elasticity with respect to farm income Y_F is the short run elasti plus the elasticity with respect to E. The elasticity of Q_{FL} with respect to E is 0 increase in Y_F' is expected to raise E approximately 1.57 percent (cf. equation 15, C elasticity with respect to Y_F' roughly is $0.057 + (0.126)(1.57) = 0.25$ when unemploy the elasticity with respect to E is not adjusted adequately for U, it is only estima the average U from historical experience.

[c]The short run elasticity with respect to Y_R divided by the adjustment coeffici in equation 20. The long run elasticity with respect to Y_{NF} is much less than with influence E.

[d]The long run elasticity with respect to Y_F' is the short run elasticity 0.067 (long run Y_F' component of E, or 0.091, divided by the adjustment coefficient 0.46. I $(0.067 + 0.091)/0.46 = 0.35$. Similar computations are made for equation 20. The lo Y_F' is much greater than with respect to Y_{NF} because a reduction in the former affect the adjustment coefficient 0.5 indicates that slightly over three years are requirec adjustment after the explanatory variables have changed. Because the explanatory va diately, one to three years are added to the three year adjustment indicated in the

Q_{FL} with respect to farm income per family worker Y'_F and factory income
the mean from selected equations in Tables 1 and 2

run (Years)	Equation 12 Short run (1-2 years)	Equation 12 Long run (4-6 years)		Equation 20 Short run (1-2 years)	Equation 20 Long run (4-6 years)	
Y'_F[b]	Y_R[a]	Y_{NF}[c]	Y'_F[d]	Y_R[a]	Y_{NF}[c]	Y'_F[d]
--	-0.087	-0.189	--	-0.107	-0.208	--
25	-0.067	-0.144	0.34	-0.080	-0.156	0.35
22	-0.046	-0.099	0.30	-0.054	-0.104	0.30
--	-0.025	-0.054	--	-0.027	-0.052	--
--	0.004	0.008	--	0.000	0.000	--
--	0.017	0.037	--	0.000	0.000	--
.23	-0.050	-0.108	0.31	-0.028	-0.055	0.36
.26	-0.071	-0.153	0.35	-0.041	-0.080	0.26

respect to Y_R. Since $Y_R = Y_{NL}/Y'_F$, the short run elasticities with respect

spect to farm income Y_F is the short run elasticity 0.057 (for U = 5 percent)
. The elasticity of Q_{FL} with respect to E is 0.126. A sustained one percent
approximately 1.57 percent (cf. equation 15, Chapter 8). The total long run
is 0.057 + (0.126) (1.57) = 0.25 when unemployment is five percent. Because
ot adjusted adequately for U, it is only estimated well within the range of
nce.

espect to Y_R divided by the adjustment coefficients 0.46 in equation 12 and 0.52
ity with respect to Y_{NF} is much less than with respect to Y'_F because Y_{NF} does not

spect to Y'_F is the short run elasticity 0.067 (for U = 5, equation 12) plus the
divided by the adjustment coefficient 0.46. The total elasticity is, therefore,
computations are made for equation 20. The long run elasticity with respect to
to Y_{NF} because a reduction in the former affects farm equity. The magnitude of
tes that slightly over three years are required to make 90 percent of the total
ables have changed. Because the explanatory variables do not change imme-
to the three year adjustment indicated in the equation.

respect to farm income may be as high as 0.36 according to equation 20.[4] Because the interrelationship between labor mobility, unemployment and a change in equity E was not stressed in the empirical analysis, it is not feasible to estimate the response to a change in E for values of U other than five and 10 percent. That these unemployment rates are quite realistic and well within the range of historical experience is indicated by the average unemployment in the 1926-59 and 1946-59 periods in Table 3. It seems reasonable that the long run response to a given income differential is less conditional upon the level of unemployment than is the short run response. Given time, family workers can filter into scattered non-farm jobs despite high general unemployment.

The long run elasticity of Q_{FL} with respect to a change in the non-farm income Y_{NF} may be as high as -0.21 according to equation 20. The long run elasticity with respect to Y_{NF} is lower than with respect to Y_F' because a sustained drop in farm incomes leads to a weakening of the farm financial position. Eventually the farmer may not be able to meet fixed

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[4]The elasticities computed from equation 13 are not included in Table 3 although the equation has certain logical and statistical advantages. The short run elasticities computed from equation 13 are slightly greater than those computed from equations 7, 12 and 20. The long run elasticities computed from equation 13 are less; the maximum long run elasticity for U = 0.05 is 0.27 compared with 0.34 and 0.35 based on equations 12 and 20.

financial obligations and loan foreclosure or other difficulties may result. To summarize, a 10 percent fall in farm income may decrease the number of family workers up to 3.5 percent in the long run. A 10 percent rise in non-farm incomes may decrease the number of farm family workers as much as two percent. But if unemployment is high, the response of workers to a change in income may be much lower than these estimates according to Table 3.

The elasticity estimates are from data covering a period of falling family employment and relative farm income. The results, therefore, are relevant for such conditions, and it is hazardous to gage the impact of large <u>increases</u> in farm income or employment from Table 3.

Table 3 emphasizes the important interaction between the rate of unemployment and the income elasticities. The critical level V at which elasticities reach zero for equation 7 is 0.14, equation 10 is 0.25, equation 12 is 0.21, equation 13 is 0.20 and for the trial and error equations 16 to 19 is 0.20. In several depression years, national unemployment equaled or exceeded the critical value indicated by the above equations. Unemployment of three percent of the national labor force is consistent with seasonal and frictional labor adjustments. Equation 7 indicates that the short run effectiveness of relative incomes in bringing adjustments in the farm labor force is decreased 25 percent when unemployment increases from three percent to six percent (unemployment in some recent years has been six percent or slightly greater). The results emphasize the close economic relationship between the farm and non-farm sectors. It also emphasizes that a government policy encouraging high national employment also facilitates adjustments in agriculture.

Shifts in the family labor function

The number of family workers in agriculture declined 43 percent from 1926 to 1959, or at an average compound rate of 1.7 percent per year. Some of the forces responsible for this change may be evaluated from the estimated labor functions. A measure of the relative influence of income, equity and time on the number of workers may be judged by the standard partial regression coefficients. If U equals zero, the standard partial regression coefficients of equation 7 are -0.16 for Y_R, 0.39 for E and -1.15 for T. If U equals 14 percent, the standard partial regression coefficient of Y_R is zero. The results indicate that the relative influence of Y_R on Q_{FL} is small and is overshadowed by E and T. If U equals zero, the actual coefficient of Y_R is -0.86 and of T is -14.57 in equation 13. The index of relative incomes Y_R would have to fall 17 points in one year to decrease Q_{FL} in the short run as much as forces associated with the time variable.

The actual change in Q_{FL} for a given period of time depends on the trend in the variables as well as on the relative impact of a given variable on Q_{FL}. Equation 7 predicts a total decline of 42 percent in the family labor force -- the actual decline was 43 percent. The value of Y_R was nearly the same in 1926 as in 1959. Even if the coefficient of income were large it would not explain the decline in Q_{FL} from 1926 to 1959. Ceteris paribus, the improvement in equity E from 1926 to 1959 would have increased Q_{FL} by eight percent according to equation 7. It is apparent that nearly the entire decline in Q_{FL} is associated with the time variable T. The results indicate that the family labor force has decreased approximately 150,000 per year due to factors associated with the time variable. This result is based on the coefficients of T in equations 5 to 10, 13, and 14 to 19. (This result also agrees with the long run coefficients of equations 12 and 20.)

Implications of policy alternatives

Various instruments of policy might be considered, given the goal of narrowing the gap between farm and non-farm incomes. It is not the purpose of this study to state what the goal *should* be, or what instruments *should* be used to attain a given goal. The purpose is rather to point out the implications of various instruments such as continuation of present policies, free prices, production controls, rationing of technology and inputs, and direct subsidies, if narrowing the income differential is a goal of society.

It the ratio of farm to factory worker income is now 0.5 and the equilibrium ratio is 0.7, the equilibrium may be achieved, _ceteris paribus_, by reducing the farm family labor force 25 to 30 percent.[5] One alternative is to continue with essentially the current policies. Tables 1 and 2 indicate that influences such as improved education, communication, transportation, and labor saving investment reflected by the time variable reduce family employment in agriculture up to 150,000 per year. This is more than two percent of the current annual family labor force. The implication is that forces represented by T would reduce family employment 1.5 million, or 27 percent in 10 years. This is substantially

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[5]The required 25-30 percent decrease in number of family workers is computed as follows:

(a) $Y_F/Q_{FL} = .50\ Y_{NL}$

where Y_F is total farm income, Q_{FL} is number of family workers and Y_{NL} is income per worker in factories. Equation (a) indicates that per worker farm income is 50 percent of per worker factory income. To increase per worker farm income to 70 percent of Y_{NL}, simply reduce Q_{FL} 28.6 percent, i.e.

(b) $Y_F/(1-0.286)Q_{FL} = 0.70\ Y_{NL}$.

An equilibrium farm income only 70 percent that of non-farm income is assumed because of the composition of Q_{FL} (includes many part time, young, inexperienced workers) and because of other considerations such as psychic farm income, and different degrees of skill. Some basis for unequal equilibrium income also exists because of differences in the concept and measurement of income in agricultural and non-agricultural industries.

the reduction needed to equate returns in farm and non-farm employment. Unfortunately, it is not reasonable to conclude that if we merely "tread water" for 10 years the farm income problem will be solved. The relative income in agriculture did not improve from 1926 to 1959 because the outmovement of workers was just rapid enough to compensate for the reduction in total residual income resulting from adoption of output increasing (income decreasing) farm technology. That is, the reduction in number of family workers was offset by the decrease in residual farm income, leaving relative income <u>per worker</u> unchanged. There is little reason to believe that this tendency will decline in the future. This conclusion leaves small hope that the gap between farm and non-farm incomes will narrow appreciably in the near future without additional programs.

Because the demand for farm products is inelastic, total farm income is depressed by the rapid adoption of new technology and investment in output increasing capital. If institutional or other barriers to off-farm migration had been great, income per worker in agriculture would have decreased. Perhaps it is notable that farm technology and capital investment were sufficiently labor saving and off-farm opportunities sufficiently great to prevent an even greater deterioration of relative farm income per worker.

Let us consider the feasibility of free markets for bringing the necessary adjustment based on the results in Table 3. The analysis is partial -- the outmovement of workers reflected by the time variable is expected to continue at a rate that just compensates for the total income reducing effect of improved technology. Assuming that a shift to free markets reduced farm incomes 35 percent for five years, the family labor force would be reduced approximately 10 percent according to Table 3. (A reduction in family employment will take place <u>without</u> any additional fall in relative income, but the drop is assumed to be 10 percent <u>greater</u> because of free prices.) Given the unlikely prospect that total farm income returned to present levels after the adjustment and that workers consequently did not return to agriculture, only one-half or less of the required adjustment of the farm labor force would be made.[6] This example is

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[6]How total gross farm income might be influenced by a reduction in Q_{FL} depends on the influence of labor on farm output. Appendix A indicates that the marginal product of farm labor is low and a reduction in Q_{FL} would have little influence on farm output and, hence, on total gross farm income. That labor would not move into agriculture with a return to higher incomes is based on an assumed irreversible labor function. The assumption that total income in agriculture would return to present levels in the long run is overly optimistic and depends on the movement of resources such as operating inputs and durables with high elasticities of production. The response of these resources (and farm output) to price changes is discussed later in this study. If prices fell far enough so that the financial structure of agriculture was impaired, the movement of workers out of agriculture might be more rapid. This possibility is ruled out by the assumption that the social and political upheaval would result in government action (continued on next page)

somewhat unrealistic but is an attempt to combine the most favorable elements of adjustment to a free price equilibrium. The actual adjustment might be much less favorable than depicted. For falling farm incomes to remove the imbalance in relative income, the outmovement of workers must be greater proportionately than the fall in income. The inelastic response of family workers to relative income indicates that a fall in farm income would result in an even greater disparity in per worker incomes in the farm and non-farm sector, even in the long run.

How adjustments due to adoption of labor saving machinery, education and training for non-farm jobs, etc. would be affected by a fall in farm is difficult to judge. The above conclusions are based on the assumption that these adjustments depicted by T and S_M in the estimated equations would be unaffected by a free market system or would be compensated by changes in the rate of adoption of output increasing tech-

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(footnote continued from previous page) before a general farm financial crisis occurred. Finally, the assumed 35 percent reduction may be too great, but a smaller reduction would be even less effective in moving family workers.

The analysis of the influence of free prices on farm numbers is superimposed on the existing structure. It is a partial analysis abstracting from technological and investment effects. The underlying assumption is that any drop in farm income due to output increasing technology would be just compensated by the decrease in the number of family laborers due to education, etc. and other factors associated with T.

nology.

Increasing the mobility of farm workers through improved skills, subsidies or loans to migrants and through national employment agencies to disseminate job information is desirable from the standpoint of economic efficiency and societal welfare. If the annual marginal value product (contribution to the real income of society) is much higher in non-farm employment, the gains to society are large indeed from migration of 150,000 farm workers per year. National income is increased a great deal by the migration of farm people to jobs paying $2000 per year more than their former employment. Even if this is only a crude and somewhat overstated indication of the real gains to the individual (salary) and to society (marginal value product), it does emphasize some of the actual and potential benefits of a mobile population. There are few gains in increasing the mobility of the farm population if national unemployment is high. In fact, the national income may be reduced by migration if unemployment is high. The marginal product of the unemployed in agriculture essentially is zero, but in urban areas is negative because of unemployment compensation and other social costs. It follows that policies to encourage full national employment and a vigorous economy have important ramifications for farm people as well as for non-farm people.

The influence of various policy instruments on factors represented by time T is difficult to judge. Active policies may be necessary to maintain the employment flow at its high present level. That the family labor force annually decreased by 150,000 workers because of influences represented by T, is not unreasonable for the 1926 to 1959 period, but it is not meaningful for extended projections. If we extrapolate from T, the number of family workers in agriculture would be zero by the year 2000. The annual outmovement of workers will decline in the future, of course.

An alternative government policy is to reduce farm output (raise total farm income) by production controls, rationing of inputs and technology, etc. These measures to restrict output are more effective, especially in the short run, than measures to increase mobility in raising per worker income in agriculture. These measures are less efficient from an economic standpoint, however. The measures do not deal directly with adjustments necessary to attain the optimum resource mix and maximum real output of the economy. But they are effective in raising farm income while the necessary adjustments are taking place. How the income increasing effects of these programs and of direct price supports and subsidies influence labor mobility and per worker farm income may be judged from Table 3. The direct effect of an increase in total farm income is to retard slightly the outmovement of family labor. A government program which increases farm income 10 percent may reduce the outmovement of workers more than three percent in the long run based on the results in Table 3. This is a small influence compared with the annual migration of more than two percent of the family labor force for reasons not directly associated with short run income. The empirical results also indicate that the long run response of workers to income is inelastic. The implication is that a given percentage increase in farm income will not increase the number of family workers by a similar percentage. Thus, a farm program providing a sustained increase in total farm income will increase income per worker, even in the long run. There need be no conflict between the immediate aims of the policy to increase income per worker and the long run consequences according to these results. In the long run, the effect of a program designed to increase per worker income would be dampened by restrained migration. When the influence of higher farm incomes on the rate of technological innovation, investment in labor saving machinery, etc. is considered, the net effect of higher farm incomes on labor mobility (and on per worker income) becomes unclear.

Trends and projections

Figure 5 indicates the number of family workers in agriculture dropped sharply from the mid 1930's to the present. The increase in labor numbers during the depression years of

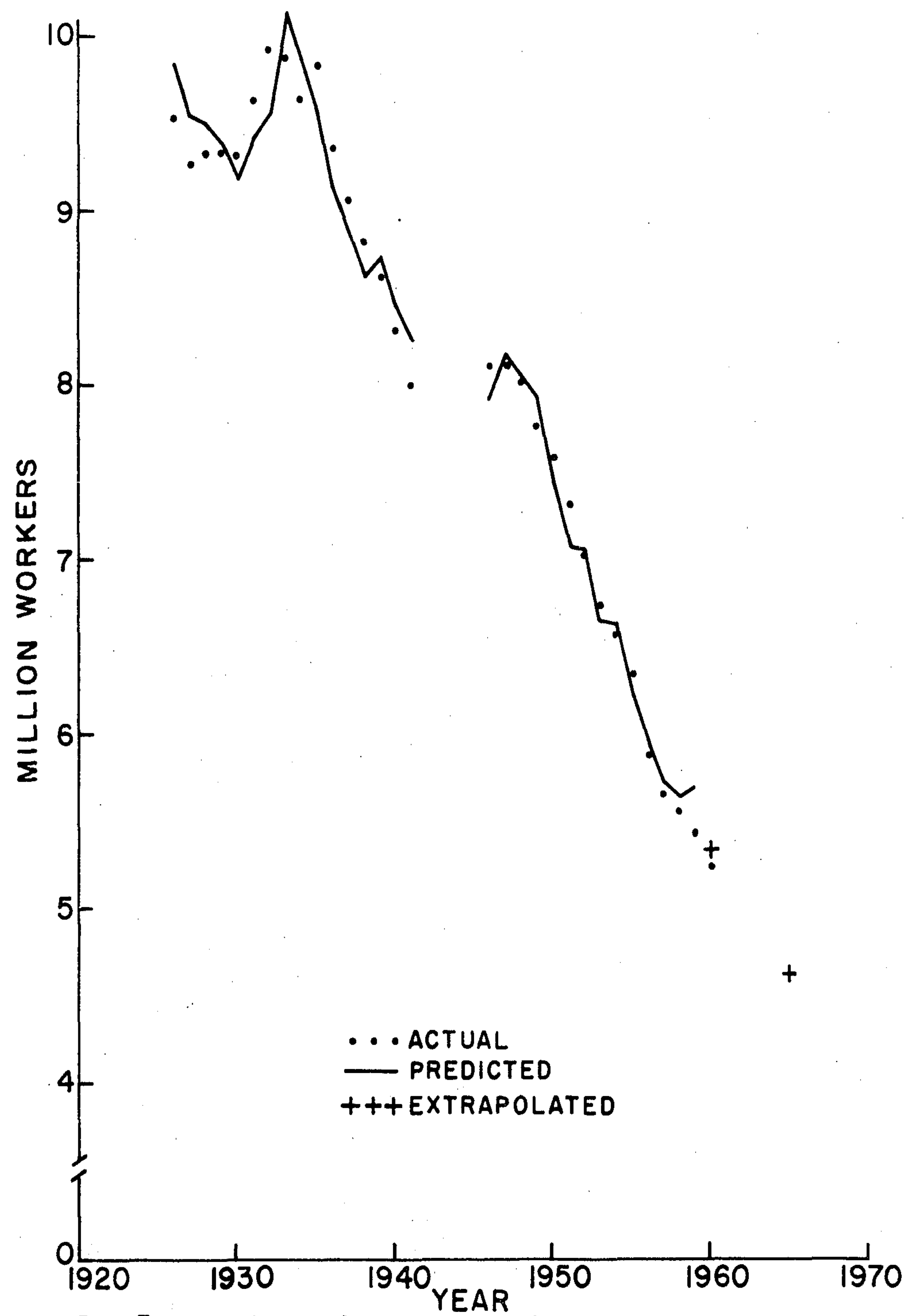

Figure 5. Trends in numbers of family workers in agriculture from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 7

the 1930's indicates labor mobility is related to economic conditions. The out-migration was interrupted by World War II but continued at nearly the same linear rate during the postwar years that was established in the late 1930's. There is some evidence that the rate is slowing in recent years. Out-migration remains large, however.

The actual values are predicted by equation 7. In general, the predictions are quite accurate. The number of workers is estimated for 1960 by extrapolating from 1959 values of explanatory variables. The actual number of workers is overestimated slightly, but the error is small. The number of family workers is projected to 1965 from equation 7 assuming relative income and equity will remain at 1955-59 levels. The projected number of family workers for 1965 is slightly over 4.6 million. The number approximately is 14 percent below the predicted 1960 number. The results suggest that the number of workers in agriculture will be considerably less in 1965. Whether this reduction will increase per worker income in agriculture depends on movements in total net income.

The Market for Hired Labor

The market for hired labor has been analyzed quantitatively by Johnson (74), Schuh (103) and Griliches (46). Griliches estimated the number of hired workers employed in agriculture as a function of the ratio of hired labor wages to prices received by farmers, and of the lagged dependent variable. The two independent variables gave R^2's up to 0.98 in equations fitted to annual data from 1912 to 1956.

Johnson (74) estimated the demand for hired labor over various periods of time by single and simultaneous equations. He considered the number of hired laborers employed in agriculture to be a function of the hired farm wage rate, prices received by farmers, the value of farm machinery, time and lagged employment. In the simultaneous model, the wage rate was also made endogenous. In general, the coefficients of prices, time and lagged employment displayed the correct signs but the significance was sensitive to the specification. The coefficient of the machinery variable was positive and highly significant. Johnson specified employment and farm wages as jointly determined by the lagged employment, time and a composite non-farm wage variable which equaled zero when unemployment reached 20 percent. The supply adjustment coefficient was estimated as 0.19. The price elasticities obtained by the above authors are discussed later. The analysis by Schuh was similar to Johnson's simultaneous estimates and is not discussed.

Specification of the demand function for hired labor

In this study, the demand for hired labor is estimated by a least squares single equation and also by a limited information simultaneous system. In the interdependent system, the market for hired farm labor is estimated jointly with demand and supply functions for other inputs and farm output. The number of hired workers in the single demand equations is specified as a function of the wage of hired farm labor, prices received by farmers for operating inputs and machinery, the stock of all productive assets, a variable representing government policies, and slowly changing influences represented by a time variable. These variables are defined explicitly as follows:

Q_{HLt} The dependent variable is the number of hired workers employed in agriculture during the current year, measured in 10 thousands (30, 118).

$(P_{HL}/P_R)_t$ The current year index of the ratio of the farm wage rate to prices received by farmers for all farm commodities, expressed as a percent of the 1947-49 average (120). In addition, the past year ratio is also included.

$(P_{HL}/P'_P)_t$ The current year index of the ratio of the farm wage rate to prices paid by farmers for operating inputs and machinery; expressed as a percent of the 1947-49 average (120). The past year ratio is also specified.

S_{pt} The total stock of productive farm assets on January 1 of the current calendar year (4, 123). The variable is in billions of 1947-49 dollars.

G_t An index of government agricultural policies (3, 34).

T Time, an index composed of the last two digits of the current year.

All variables are national aggregates for the calendar year from 1926 to 1959, excluding 1942 to 1945.

The least squares demand equations

The coefficient of $(P_{HL}/P_R)_{t-1}$ is the only significant coefficient of the three price variables in equation 21, Table 4. The coefficient of the government program variable G is negative and significant in the equation. The result is consistent with the hypothesis that government programs have not inhibited farm labor mobility. No strong inferences can be made, however, because of the crude formulation of the variable. G is not included in subsequent equations.

Equations 22 and 23 are included to demonstrate the role of current and past prices in the labor function. The magnitude and significance of the coefficients of lagged prices are greater than current price. If the price of operating

Table 4. Demand functions for hired labor Q_{HL} estimated by least squares with annual dat excluding 1942 to 1945; coefficients, standard errors (in parenthesis) and rela

Equation and transformation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_{HL}/P_R t	P_{HL}/P_R t-1	P_{HL}/P'_P t	P_{HL}/P'_P t-1	
21-0	0.982	1.08	345.13	-0.0043	-0.69		0.30	
	0.978			(0.2260)	(0.22)		(0.19)	(
22-0	0.978	1.06	335.58		-0.45		-0.027	
	0.975				(0.16)		(0.137)	(
22-L	0.985	1.34	2.18		-0.199		-0.0011	
	0.982				(0.051)		(0.0350)	(
23-0	0.973	0.78	339.78	-0.33		-0.0079		
	0.969			(0.20)		(0.1670)		(
23-L	0.979	1.83	2.21	-0.157		0.012		
	0.975			(0.066)		(0.043)		(
24-0	0.978	1.06	337.56		-0.46			
	0.976				(0.15)			(
24-L	0.985	1.34	2.18		-0.200			
	0.983				(0.046)			(
25-0	0.982	1.56	196.42		-0.056			
	0.980				(0.097)			
25-L	0.987	1.75	1.66		-0.072			
	0.986				(0.033)			

[a]Sources and composition of the dependent variable Q_{HL} and of the indicated independe

[b]Equations designated 0 are estimated linear in original values, those specified L ar The time variable T is untransformed in the L equations. The annual percent shift in dema is computed from the coefficient c of T as: 100(antilog c - 1).

[c]The Durbin-Watson autocorrelation statistic d'.

$_{HL}$ estimated by least squares with annual data from 1926 to 1959,
its, standard errors (in parenthesis) and related statistics are included[a]

P_{HL}/P_R t	P_{HL}/P_R t-1	P_{HL}/P'_P t	P_{HL}/P'_P t-1	S_p t	G t	T	Q_{HL} t-1
-0.0043	-0.69		0.30	1.99	-0.56	-5.19	
(0.2260)	(0.22)		(0.19)	(0.70)	(0.24)	(0.38)	
	-0.45		-0.027	2.24		-5.49	
	(0.16)		(0.137)	(0.62)		(0.37)	
	-0.199		-0.0011	0.49		-0.00800	
	(0.051)		(0.0350)	(0.19)		(0.00054)	
-0.33		-0.0079		2.10		-5.59	
(0.20)		(0.1670)		(0.85)		(0.43)	
-0.157		0.012		0.42		-0.00820	
(0.066)		(0.043)		(0.26)		(0.00065)	
	-0.46			2.21		-5.50	
	(0.15)			(0.59)		(0.37)	
	-0.200			0.49		-0.00800	
	(0.046)			(0.18)		(0.0053)	
	-0.056					-1.88	0.56
	(0.097)					(0.61)	(0.12)
	-0.072					-0.00390	0.44
	(0.033)					(0.00086)	(0.11)

nt variable Q_{HL} and of the indicated independent variables are discussed in the text.

inear in original values, those specified L are estimated linear in logarithms.
L equations. The annual percent shift in demand through time in the L equations
100(antilog c - 1).

istic d'.

inputs and farm machinery influence the demand for hired labor, it is not apparent from the insignificant coefficients of P_{HL}/P'_P in equations 21, 22 and 23. Yet there exists sound a priori basis for the variables to be important in explaining demand for labor. Some reasons why the coefficients are not significant are: (a) the variables have an important influence, but only in the long run, (b) the level of aggregation is too great, the individual effects offset each other and leave the coefficient zero, (c) the correlation between P_{HL}/P'_P and P_{HL}/P_R is high ($r = 0.88$) and causes the former variable to be overshadowed, and (d) the influence of machinery and operating inputs on demand for hired labor largely arises from technological and other non-price influences.

The influence of related inputs when the price effect is not dominate perhaps is best represented by including the predetermined stock of related inputs in the demand function. This is a principal reason for including S_p in the demand function. The coefficient of S_p is positive and significant in the demand equations. The coefficient of S_p in the logarithm equations L indicates that a one percent increase in the stock of productive assets increases the demand for hired labor one percent. The coefficient is consistent with the <u>short run</u> influence of investment in machinery and other stock on labor demand. That is, increases in the stock of machinery raise the marginal product of labor. In the long run, however, machinery and other assets substitute for labor and a negative coefficient would be expected.

The coefficients of the three explanatory variables $(P_{HL}/P_R)_{t-1}$, S_p and T, are highly significant in equation 24. Together, the variables explain 98 percent of the variation in the number of hired laborers. The slightly higher R^2 and the smaller degree of autocorrelation in the residuals indicated by d' = 1.34 in equation 24-L suggest certain advantages of the logarithm form for expressing hired labor demand.

A distributed lag adjustment model is formed by including a lagged employment variable in equation 25. The coefficient of Q_{HLt-1} was insignificant when S_{pt} was included and indicates there is no long run adjustment given the size of the agricultural plant. The stock variable is omitted in equation 25 and the coefficient of lagged employment is significant. The significant coefficient indicates that the adjustment coefficient approximately is 0.5. The rates of adjustment for hired and family labor to changes in explanatory variables appear to be approximately equal according to Tables 1, 2 and 4. The coefficients of price and time are lower in adjustment equation 25 than in the conventional equation 24. It is difficult to ascertain the structural validity of adjustment equation 25, but the high R^2 indicates that the equation is a useful predictive device.

Demand for hired labor estimated by limited information

In Chapter 2, various considerations suggested that the case for interdependence of supply and demand was stronger for hired farm labor than for any other major agricultural input. The assumption of the simultaneous model is that current agricultural employment and wage rates are determined simultaneously by farm variables as well as by non-farm variables including factory wages and unemployment. The limited information model, discussed in earlier chapters, is estimated from variables specified in the single equation plus a farm numbers variable N. Prices are deflated by the implicit price deflator of the gross national product. The limited information demand equation, estimated with annual data from 1926 to 1959, excluding 1942 to 1945, is

$$(26)\quad Q_{HLt} = 1566 - \underset{[-1.69]}{4.30\,P_{Ot}} + \underset{[0.81]}{2.06\,P_{Mt}} - \underset{[-0.46]}{1.55\,P_{HLt}} + \underset{[0.68]}{2.28\,P_{Rt}} - \underset{[-2.12]}{9.16\,N_t} - \underset{[-0.15]}{0.44\,(P_{HL}/P_R)_{t-1}} - \underset{[-0.14]}{0.38\,S_{pt}} - 1.18\,T$$

where P_O is the price of operating inputs, P_M is the price of farm machinery. Standard errors were not estimated; elasticities are included in brackets below the coefficients. The last three variables $(P_{HL}/P_R)_{t-1}$, S_{pt} and T are predetermined, the remainder endogenous. The equation indicates that operating inputs are complements; machinery inputs are substitutes for hired labor in the market. Based on equation 26, a one percent fall in the price of machinery tends to be associated with a 0.8 percent decrease in demand for hired labor. The negative coefficient of N indicates that decreases in the number of farms (expansion in farm size) is associated with an increasing demand for hired labor. It seems reasonable that as farms expand in size, it is necessary to supplement family labor with hired labor.

The coefficients of P_{HL} and P_R possess the expected signs. The magnitudes of the coefficients and dominance of current variables conflicts with the single equation estimates. The least squares estimates appear to be more reasonable, however. The results conform with those of previous limited information estimates of input demand in this study. That is, the magnitudes of the coefficients appear unusually large. The cause is difficult to pin point, but may arise from multicollinearity and underidentification. Because the signs of the coefficients generally are consistent with logic and because there is no exact test of the structural reliability of the equation, it is included as a tentative hypothesis. Structural inferences in the following pages are based primarily on the single equation results.

Price elasticity of demand

The demand elasticities estimated from the single equations in Table 4 are relevant only for "average" national employment conditions from 1926 to 1959. The heroic assumption of the linear single equation is that a shift in the farm wage or price variable will shift the demand quantity, irrespective of the level of unemployment in the non-farm sector. The estimated coefficients actually would be much lower for periods of high unemployment.

The logarithm equations displayed certain advantages for expressing demand for hired labor, hence, the elasticity estimates are based on equations 24-L and 25-L. Equation 24-L indicates that the point estimate and 94 percent confidence interval of the demand elasticity and with respect to P_{HL} or $-P_R$ is -0.20 ± 0.095. The adjustment equation 25 indicates that the short run demand elasticity with respect to P_{HL} or $-P_R$ is -0.072 ± 0.068. The long run elasticity -0.14 is found by dividing the short run elasticity by the adjustment coefficient 0.56. Approximately 90 percent of the long run adjustment is completed in five years. The results indicate that a 10 percent fall in farm product prices or increase in farm wages would decrease the number of hired farm laborers approximately one percent in one or two years and up to two percent in five years.

The distributed lag models estimated in logarithms by

Griliches (46) indicated the short run demand elasticity with respect to P_{HL}/P_R is -0.10 and the long run elasticity is -0.44. Johnson's (74) estimates of the elasticity ranged from near zero to -0.9, depending on the period studied and the model specification. On the basis of the results in Table 4 and from other studies, it is apparent that demand for hired labor is inelastic even in the long run. In the short run when unemployment is high, the elasticity is nearly zero.

Shifts in demand

The number of hired laborers employed in agriculture declined 44 percent from 1926 to 1959, or at an average compound rate of 1.75 percent per year. It is interesting to note that the number of family laborers declined 43 percent during the same period. The two components of total farm labor behaved much alike. The relative price P_{HL}/P_R of hired labor increased 100 percent in the 33 years. Because of the negative relationship between employment and price, equation 24 indicates that 10 percent of the decline in the number of hired laborers from 1926 to 1959 arises from the increased relative wage rate. After allowing for errors in measurement due to failure to include other prices, adjustments for unemployment, etc., a large proportion of the total decrease in employment of hired labor remains to be explained by factors other than short run price. The coefficient of T in equation 24-L indicates that employment fell 1.8 percent per year due to factors associated with the time variable. Equation 25-L provides nearly the same estimate of the long run rate of decline in Q_{HL} from influences represented by T. Some of these influences, discussed in the family labor section are: (a) the growing awareness of alternative opportunities and means of mobility provided by improved transportation, communication and education, and (b) the "push" of labor saving machinery, specialization, technology, etc.

Trends and projections

The trend in the number of hired farm laborers is similar to that depicted earlier for family labor (Figure 6). The general downward trend is interrupted by the depression and by the immediate recovery after World War II. In recent years the downward trend was interrupted, perhaps mainly due to the recession and unemployment in 1958. Equation 24-0 does not predict the trend reversal because an unemployment variable is not included in the equation. A reduced form, hybrid equation containing the supply variables would predict more accurately. Predictions from the single demand equation essentially are made with the assumption that supply conditions remain unchanged. Based on a projection of S_p = 114.4 billion 1947-49 dollars by 1965 from equation 28,

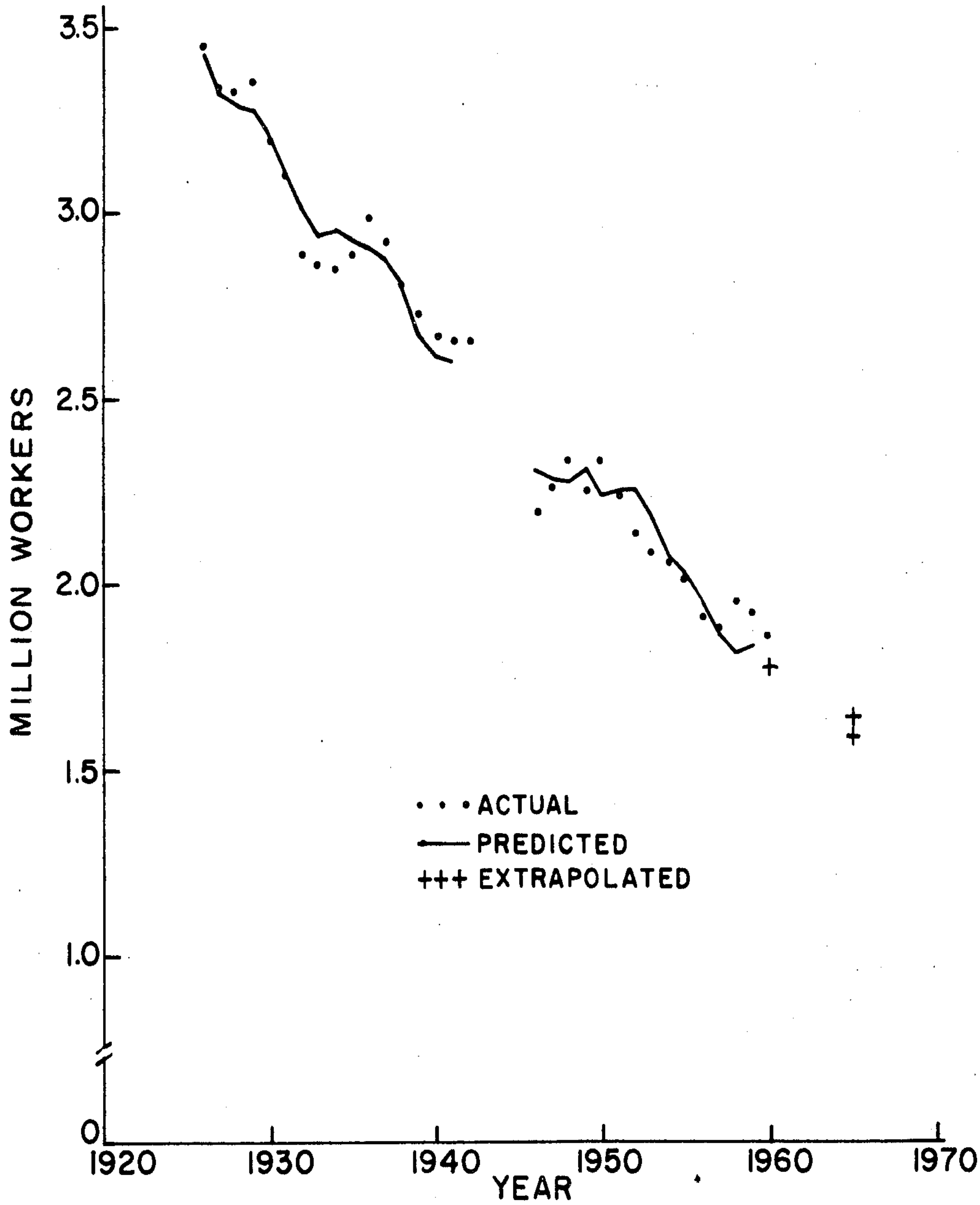

Figure 6. Trends in numbers of hired workers in agriculture from 1926 to 1960, showing actual values; and predicted and projected estimates from equation 24-0

Chapter 9, and on 1955-59 average prices, employment of hired labor is projected to be 1.64 million workers in 1965. The relative price of labor rose over 10 percent from 1955 to 1959. Assuming prices rise 10 percent over 1955-59 levels by 1965, employment of 1.58 million workers is projected for 1965. These estimates are respectively six and nine percent below predicted 1960 employment. The projected nine percent fall in employment is considered more realistic. These projections are based on "normal" conditions of national unemployment. If unemployment should rise markedly, the rate of outmovement of hired labor could be much lower.

The limited information supply equation

The supply equation for hired farm labor estimated by limited information with annual time series from 1926 to 1959, excluding 1942 to 1945 is

$$(27)\quad P_{HLt} = \underset{}{-36} + \underset{(0.056)}{0.183}\ Q_{HLt} + \underset{(0.10)}{0.43}\ P_{NLt} + \underset{(0.051)}{0.147}\left[P_{NL}(1-5U)\right]_{t-1} + \underset{(0.056)}{0.374}\ C_t$$

where C is a shift variable with values of zero from 1926 to 1941, and values of 100 from 1946 to 1959. P_{NL} is the wage rate of factory workers and U is the proportion of the national labor force unemployed. The price variables are deflated by the implicit price deflator of the gross national product. Standard errors, indicated in parenthesis below the coefficients, are less than one-half the coefficients. All coefficients display the expected signs.

The supply elasticity computed from equation 27 is 1.63. P_{HL} and Q_{HL} are endogenous in equation 27 and the limited information estimate is independent of the direction of normalization. Whether price or quantity is to the left of the equal sign in equation 27 makes no difference, the computed supply elasticity is the same.

The result indicates that a sustained one percent rise in P_{NL} tends to increase P_{HL} approximately 0.62 percent when U is at the 1926-59 average level. The coefficient of C indicates that there has been a significant upward shift in supply during the postwar period.

Summary of Empirical Results

Despite the reduction of the family labor force by 1.7 percent per year since 1926, the outmovement has not been rapid enough to increase farm income per worker. Adoption of new methods, which increase farm output faster than the demand expands for farm products, have depressed farm prices and income. The result is that the gap between income per worker on farms and in factories has not narrowed in the last 35 years. Graphic analysis reveals that movements of the total farm labor force have been consistent with relative price relationships. The relative increase in labor costs has resulted in substitution of capital for labor and in a major reduction of labor in the total input mix.

The empirical results indicate that a 10 percent reduction in farm income per family worker will result in a reduction of the family labor force by one percent in one or two years, and up to 3.5 percent in four to six years. A 10 percent increase in income per factory worker will result in a one percent reduction in the number of farm family workers in one or two years and up to a two percent reduction in four to six years. These results are conditioned by the level of unemployment. The equations indicate that as unemployment increases, the responsiveness of family workers to a change in relative income falls markedly, and reaches zero when unemployment approaches 20 percent.

The _inelastic_ long run response of family labor to relative income has several policy implications. A policy to increase outmovement of family labor by reducing _total_ farm income by a given percentage will reduce the family employment by a smaller percentage -- decreasing income _per family worker_. A policy that raises farm income will have some of its intended benefits dampened in the long run by encouraging workers to stay in agriculture. But even in the long run, the results indicate that the additional percentage of workers staying in agriculture will be less than the total increase in income. The result is that income _per worker_ will be increased, even in the long run, but not to the extent per worker income is increased in the short run.

The results indicate that up to 150,000 family workers are moving from agriculture each year due to long run adjustments to relative income, barriers to entry into farming posed by high capital requirements, farm consolidation and labor saving equipment, and due to improved education, communication, and transportation. Assuming relative farm income per worker remains at the 1955-59 level, the number of family workers in agriculture is projected to be 4.6 million in 1965, a reduction of 14 percent below the predicted 1960 number.

Single equation demand functions for hired farm labor indicate that a 10 percent increase in the farm wage rate (or decrease in prices received by farmers) will reduce employment of hired labor one percent in one or two years and by two percent in four to six years. The rate of adjustment to the equilibrium or desired employment for both hired and family workers is estimated as 0.5 per year. That is, approximately one-half of the gap between the desired employment and the current employment is made in one year.

Based on a 10 percent increase in relative wage rates from the 1955-59 average, employment of hired farm labor is projected to decrease nine percent from predicted 1960 values by 1965.

The supply equation for hired labor indicates that a sustained one percent increase in the wage of non-farm labor will increase farm wages 0.62 percent. The results again indicate the close interaction between the farm and non-farm sectors of the economy. Policies of the government, labor unions or industrial management which influence national unemployment and wages of non-farm labor have a large impact on the income and mobility of farm labor.

CHAPTER 11: AGGREGATE OUTPUT SUPPLY FUNCTIONS AND ADJUSTMENTS

Much of the current policy debate is centered on the nature of the response of output to prices in agriculture. Some persons contend that the supply elasticity is large enough to bring needed resource, output and income adjustments in a few years. At the other extreme, some individuals imply that the aggregate supply function is backward sloping because farmers increase output to meet fixed expenses when prices fall. The latter view, when coupled with a supply curve shifting faster than the demand curve to the right, presents very bleak prospects for the price system to bring needed resource, output and income adjustments in agriculture. The above are two extreme concepts of the nature of aggregate supply in agriculture.

A less extreme view is that supply response is low in agriculture and that the price mechanism will not bring adjustments that equalize incomes in the farm and non-farm sector. Many individuals holding this view still favor free markets because they consider the gains in freedom (to make individual decisions) more than compensate for the additional income that might be gained under a more controlled agriculture. Unless complete freedom has an infinite price, the decision regarding the optimum degree of controls cannot be made without knowledge of the income sacrificed for each additional degree of freedom. The analysis in this chapter is intended to provide basic information necessary to predict the implications of various policy instruments, including freedom from controls. We attempt to measure both the time and size dimensions of the supply response to price in agriculture. It is hoped that the analysis will resolve some of the conflicting concepts about the nature of product supply in agriculture. The aggregate supply response depends fundamentally on the resource flexibility in agriculture. Hence, it is logical for this study of resources to culminate in an explanation of aggregate supply in agriculture. The procedure is to base estimates of supply on previously estimated input demand functions and on direct estimates of the supply function. The U.S. farm output of crops and livestock is estimated by least squares. In addition, the sales of agricultural products (current output less changes in farm inventories) is estimated by least squares and by limited information simultaneous techniques.

In recent years, a number of excellent studies have dealt with the supply response of many individual farm commodities (cf. 82, 92). These studies unfortunately do not provide a basis for inferences about the aggregate supply response. Opportunities for substituting one commodity for another are great because farm resources are flexible among commodities, i.e. the same resources can be used to produce any one of several products. Perhaps many inferences about aggregate supply response have been based on observations of the relatively large supply elasticities for individual farm commodities. It is difficult to determine aggregate supply elasticity by aggregating supply elasticities for corn, oats, hogs, beef, etc. A simple and useful approach is to estimate the aggregate supply from aggregate output and price variables in macro functions or from input demand functions.

Several authors (55, 68, 72) have attempted to deduce the nature of aggregate supply response on the basis of resource flexibility in agriculture. In general, these non-quantitative studies conclude that the supply elasticity in response to falling product prices is low because there are few alternative uses for farm resources outside of agriculture.

In 1960, Griliches (43) published a quantitative estimate of the aggregate output function for agriculture. His most successful equations depicted output as a function of relative price, weather, trend and lagged output. The price variable was specified as the ratio of prices received by farmers to prices paid by farmers for items used in production, including interest, taxes and wage rates on March 15 of the current year. Inclusion of relative price in the previous year, prices received deflated by prices paid for items used in production only (excluding interest, taxes and wage rates), farm wage rates, farm income, non-farm income, unemployment in the non-farm economy, land prices and lagged weather did not improve the least squares equation. Inclusion of lagged output in the output function reduced the extent of autocorrelation in the residuals, but the coefficient of the lagged variable was highly sensitive to the specification of the time period and variables. The Griliches study, therefore, did not provide reliable estimates of the long run elasticity and adjustment (or expectation) coefficients. The equations indicated that the short run aggregate supply function is shifting to the right at the rate of 1.5 to 1.7 percent per year, with the shift accelerating in recent years. Estimates of the price elasticity of output are discussed later in this chapter.

Specification and Estimation of the Aggregate Supply Function for Farm Products

Two concepts of the agricultural supply quantity are used in this chapter. The first, agricultural output O, is the production of feed and livestock during the current year, excluding interfarm sales, seed, and crops fed to livestock. It represents the current product of agricultural resources available for eventual human consumption. The concept is considered the most relevant long run measure of supply quantity since it is closely tied with the resource structure and is not influenced by fluctuations of non-productive farm inventories.

The second measure of the supply quantity Q_S is output O less changes in farm inventories of livestock and feed. Q_S measures the quantity of farm commodities entering the marketing system in a given year. It is useful in explaining current farm prices. It is not necessarily a realistic indication of the production potential because inventory changes obscure the true output-input relationships. That is, farm inventories placed on the market may represent superfluous past output held for speculative purposes or non-productive inventories such as culled livestock. Since there is no production period for farm inventories, decisions regarding the level of inventories can be based on current supply and demand for farm inputs and products. For this reason, the supply concept Q_S which includes inventory changes is estimated as part of an interdependent system of demand equations for farm products and demand and supply equations for farm inputs. The supply concept O is analyzed only by ordinary least squares. The assumption is that current output is predetermined by past prices P_R/P_P, durable input levels S_p, government programs G, weather W, and trend T. The output supply function is

$$(1) \qquad O_t = f((P_R/P_P)_{t-1}, S_{pt}, G_t, W_t, T) .$$

The technology or productivity variable T' is the aggregate measure of output per unit of input in agriculture. It is composed of a long term trend (approximately T) determined by efficiency (management, specialization, etc.) and technology (changes in the true physical production function). Short term fluctuations in the productivity variable T' are determined mainly by the weather. Thus, in a second formulation of equation 1, T' is substituted for W and T. Given the level of aggregate inputs and T', the output is also known. It follows that the variables P_R/P_P, S_p and G primarily are concerned with predicting the aggregate input level in agriculture. But with the beginning year stock of productive assets S_p in the function, only operating inputs, labor and current inputs of durables are left to be determined by P_R/P_P and G.

Since durable assets and labor have little short run effect on output, the price variable primarily reflects the short run influence of operating inputs. Equation 1 may be regarded as a dynamic agricultural production function with price substituted for the quantity of operating inputs. The supply equation is extremely simplified and is short run. It can be made long run by substituting an investment function for S_p into the supply function. The supply function is specified in a highly simplified form to avoid statistical complications. But from knowledge of the input structure (investment function) much can be learned about the nature of supply elasticity in agriculture.

There are several reasons for arguing that short run supply elasticity has increased. As the proportion of purchased, flexible, operating inputs in the resource mix increases, opportunities become greater for adjusting output to price changes. More emphasis on cash, non-farm produced resources makes farmers' short run net returns more sensitive to price changes. Switching from slowly reproducable farm produced resources to non-farm inputs with high production elasticity and input supply elasticity, is expected to increase the farm output supply elasticity. More education and emphasis on management increases farmers' awareness of the gains from optimum adjustments to price changes. Improved outlook information also might be expected to increase the supply elasticity.

Other influences such as gradual awareness of the cyclical nature of agricultural production (commodity) cycles may tend to reduce the short run supply elasticity. Increased application of inputs, given the technology, moves agriculture farther up the aggregate output-input curve, lowering production and supply elasticities. Finally, improved technology and increasing proportions of flexible inputs may raise the marginal response to a price change. But because the elasticity is computed at a larger output for any given price, the magnitude of the elasticity may remain unchanged or may decline. The supply elasticity is (dQ/dP) (P/Q), and if the decline in the ratio P/Q is more rapid because of improved technology than is the increase in marginal response dQ/dP, the supply elasticity will decline.

To determine if the supply elasticity has increased, two methods are used. The first is to include separate price variables for (a) 1926 to 1941 and (b) 1946 to 1959 in a supply equation including other variables for the 1926 to 1959 period. If the estimated coefficients of the separate price variables are significantly different, the null hypothesis that the supply response or elasticity has not changed is rejected. The influences other than price are assumed to be homogeneous over the entire period. Some of these influences, e.g. S_p, T and T' are quite highly correlated, especially over short periods. It is not considered feasible to estimate the individual effects of these variables in equations including less than 30 observations.

The second method for determining supply response through time is to include an interaction variable of price with time.[1] The interaction variable allows a gradual increase

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[1]The least squares equation for output estimated as a function of price P, time T and other variables X is

(a) $O = a + b P + c (TP) + d X.$

After the form (a) is estimated, the equation may be written

(b) $O = a + (b + cT) P + d X.$

The coefficient (elasticity if O and P are in logarithms) of O with respect to P is $b + cT$ and may either increase, decrease or remain constant through time, depending on the sign of c. If c is significant, the (continued on next page)

in the price coefficient through time, rather than a single shift as in the first method. The interaction of price with time or technology may be regarded broadly as a "real price". The fact that technology has improved permits greater production for a given price.[2]

The variables in the supply functions are defined as follows:

O The dependent variable is the production of crops and livestock on U.S. farms during the current calendar year for eventual human consumption (4). The quantity is corrected for intermediate use of resources such as farm produced seed, feed and livestock, and for farm produced power. The

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(footnote continued from previous page) hypothesis is rejected that the coefficient of P has remained stable (has not changed at a linear rate) through time.

[2]The meaning of real price may be illustrated by a simple example. In competitive equilibrium with constant returns to scale, the input cost $X_P P_P$ equals output returns $Y_R P_R$,

$$\text{(a)} \quad Y_R P_R = X_P P_P \ .$$

The expression may be written

$$\text{(b)} \quad \frac{Y_R}{X_P} = \frac{P_P}{P_R} \ .$$

It is apparent that a change in the output-input or productivity ratio $Y_R/X_P = T'$ may be interpreted broadly as a decrease in the real cost P_P/P_R (or increase in real product price P_R/P_P).

quantity is expressed in millions of 1947-49 dollars.

Q_S The dependent variable is the quantity of farm products supplied to the markets during the current year. The variable is current farm output including quantities sold from farm inventories of feed and livestock (4).

$(P_R/P_P)_{t-1}$ The past year index of the ratio of prices received by farmers for crops and livestock to prices paid by farmers for items used in production, including interest, taxes and wage rates (120). When the price variable is specified as 1926-41 or 1946-59, it is the actual observations in the period indicated, zeros elsewhere.

S_{pt} The beginning year stock of productive farm assets, including real estate, machinery, feed, livestock and cash held for productive purposes (4, 123). The variable is in billions of 1947-49 dollars.

W_t Stalling's index of the influence of weather on farm output (108, 124). Values for 1958 and 1959 are computed from the deviations from a linear yield trend.

T' An index of productivity, the ratio of farm output to all farm inputs in the current year (124).

The variable is expressed as a percent of the 1947-49 average ratio of output to input.

T Time, an index composed of the last two digits of the current year.

The variables are national aggregates and extend from 1926 to 1959, excluding 1942 through 1945. Modifications discussed earlier are introduced to allow estimation of the parameters of price for segments of the entire period.

The supply (output) function estimated by least squares

In Table 1, the coefficients, standard errors and other statistics for least squares estimates for farm output O as a function of prices, productive assets and other variables are indicated. The coefficient of each variable is highly significant and displays the anticipated sign in equation 2. A quantified measure of the direct influence of government policies G was included with the same variables as in equation 2, but the coefficient of G was not significant. The coefficient of current price variable $(P_R/P_P)_t$, included with the variables in equation 2, also was not significant. Thus, $(P_R/P_P)_t$ and G are not included in Table 1. The productivity index T' is substituted for T and W in equation 3. Together, the three variables $(P_R/P_P)_{t-1}$, S_{pt} and T' explain 99 percent of the variation in O. The coefficients are highly significant. The magnitude of the coefficient of S_p is considerably

Table 1. Supply functions for aggregate farm output O estimated by least squares ι
omitting 1942 to 1945; coefficients, standard errors (in parenthesis) an(

Equation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant	P_R/P_P t-1 (1926-59)	P_R/P_P t-1 (1926-41)	P_R/P_P t-1 (1946-59)	TP_R/P_P t-1 (1926-59)
2	0.980 0.977	1.80	-19174	35.22 (12.58)			
3	0.990 0.989	0.94	-12710	31.95 (8.59)			
4	0.980 0.976	1.79	-17929		28.43 (20.44)	32.81 (13.99)	
5	0.990 0.989	0.97	-13712		36.15 (13.13)	33.49 (9.43)	
6	0.991 0.989	0.94	-15109	49.49 (16.99)			-0.420 (0.352)
7	0.989 0.987	1.44	-7802		30.12 (13.53)	25.60 (9.59)	

[a]Sources and composition of the dependent variable O and of the indicated inde

[b]All equations are estimated linear in original values.

[c]The Durbin-Watson autocorrelation statistic d'.

estimated by least squares with annual data from 1926 to 1959,
l errors (in parenthesis) and related statistics are included[a]

	P_R/P_P t-1 (1946-59)	TP_R/P_P t-1 (1926-59)	S_P t	W t	T	T'	O t-1
.)							
			261.35 (44.20)	87.57 (13.61)	211.69 (38.16)		
			123.17 (32.33)			258.99 (19.59)	
)	32.81 (13.99)		254.68 (47.63)	88.71 (14.09)	202.78 (44.04)		
)	33.49 (9.43)		129.62 (36.09)			260.99 (20.45)	
		-0.420 (0.352)	132.29 (32.98)			276.06 (24.14)	
)	25.60 (9.59)					270.69 (21.17)	0.223 (0.077)

0 and of the indicated independent variables are discussed in the text.

lues.

less, of price slightly less, than the comparable coefficients in equation 2. The degree of autocorrelation, indicated by d', is greater in equation 3 than in equation 2.

To determine if the marginal response to price has changed, equations 2 and 3 are estimated with P_R/P_P divided into two subperiods. The equations provide conflicting estimates of the direction of change in the coefficient of price between the prewar and postwar periods. The null hypothesis that the coefficients are equal was not tested statistically but undoubtedly would not be rejected. The equations in Table 1 are estimated in original values only and indicate the marginal response to price, not the elasticities. The elasticities computed from equations 3 and 4 are discussed later.

The variables in equation 6 allow the coefficient of price to change uniformly through time. The coefficient of TP_R/P_P is not significant -- we have no basis for rejecting the hypothesis that the coefficient of price has remained stable through time.

The coefficient of lagged output O_{t-1} was insignificant when included with the variables in equations 2 and 3. The interpretation is that there is no long run adjustment given the stock of productive assets and technology. An alternative formulation is that in the long run P_R/P_P determines S_p. Therefore, we may substitute lagged output for S_p in the supply function. The resulting equation provides estimates of short run price coefficients similar to those in equations 4 and 5. The estimated adjustment coefficient, 0.78, indicates that the movement to the desired or equilibrium output is rapid. This result indicates that aggregate resource adjustments occur rapidly. The adjustment of some resources such as operating inputs takes place in a short period according to earlier results, but adjustments of durable capital and labor were found to take place over a number of years. For this reason, distributed lag equation 7 is rejected as a suitable expression of long run agricultural supply.

Elasticity of supply (output)

On the basis of the equations in Table 1 and the derived demand equations for agricultural inputs, the elasticity of farm output may be estimated over various periods of time. We first consider the short run elasticity. The elasticity of output O with respect to $(P_R/P_P)_{t-1}$ computed from equations 2 and 3 at the 1926-59 means is 0.12 and 0.10, respectively. The elasticities computed for the 1926 to 1941 and 1946 to 1959 subperiods computed at the means of these periods are both 0.10 according to equation 4. Computed from equation 5, the elasticity for the first subperiod is 0.13 and for the last subperiod is 0.10. These results provide no support for the hypothesis that the aggregate short run supply elasticity has increased between the two periods.

The output elasticity may also be computed as the sum of the elasticities of demand for <u>input</u> X_i with respect to <u>output price</u> P_R multiplied by the respective elasticities of production with respect to X_i (cf. equation 15, Chapter 2). This relationship is dynamic when we consider the input demand elasticities over various periods of time. The results in Chapter 5 indicate that the demand elasticity of operating inputs with respect to product price approximately is 0.3 in the short run (one or two years). The elasticity of durable assets S_p with respect to P_R was estimated to be approximately 0.04 in the short run in Chapter 9. Based on the production functions in Appendix A, the production elasticity with respect to operating inputs is approximately 0.3 and with respect to durables is 0.6.[3] The short run elasticity of output based on these estimates is therefore (0.3) (0.3) plus (0.04) (0.6) or 0.11. The result agrees closely with the estimates from equations 2 and 3. The elasticity of labor in production approximately is zero according to Appendix A, and therefore labor need not be included in deriving the supply

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[3] S_p is not directly included in the production functions in Appendix A, but the elasticity of production for S_p is the sum of the elasticities with respect to real estate, machinery and livestock inputs. The production elasticity of the real estate input approximately is 0.5. The production elasticities with respect to other durables is considered to be 0.1, hence, the elasticity of output with respect to S_p approximately is 0.6.

elasticity. Griliches' (43) estimates of the short run supply elasticity agree very closely with the above results. We conclude that a 10 percent drop in prices received by farmers reduces aggregate farm output approximately one percent in two years.

The intermediate and long run elasticity of farm output is found by substituting the investment function for S_p into the supply equation. Equations 2 and 3 indicate that a one percent decrease in S_p reduces farm output 0.95 and 0.46 percent, respectively. These estimates essentially are production elasticities. The estimate from equation 2, 0.95, appears too large. An average of the estimates from equations 2 and 3, 0.7, agrees quite closely with the production elasticity computed from the production functions in Appendix A. Hence, the intermediate run elasticities are based on equation 3 and on the average of the estimates from equations 2 and 3. The intermediate run (approximately four years) elasticity of S_p with respect to P_R was found to be 0.07 in Chapter 9. The supply elasticity therefore is increased (0.07) (0.46) = 0.03 (equation 3) or (0.07) (0.7) = 0.05 (average of equations 2 and 3) by the intermediate run effect of S_p. The <u>total</u> intermediate run elasticity is the short run elasticity 0.10 plus the additional intermediate component due to S_p and is 0.13 to 0.15. The intermediate run supply elasticity derived from the demand elasticities in Chapters

5 to 9 and the production elasticities in Appendix A is the component due to S_p or (0.07) (0.6) = 0.04 plus the component due to operating inputs 0.09 or 0.13. Again the labor component is omitted because the production elasticity is nearly zero. The operating input component is omitted because the response of operating inputs to P_R is zero after two years (except through S_p) according to Chapter 5. It seems reasonable to conclude that the intermediate run elasticity of output with respect to P_R is not much greater than 0.15. A sustained fall of 10 percent in prices received by farmers is expected to reduce aggregate output about 1.5 percent in four years.

The long run elasticity of output with respect to prices received by farmers may be greater than commonly supposed. Based on the analysis in Chapter 9, the elasticity of S_p with respect to P_R is nearly unitary in the long run. Equation 3 indicates that the elasticity of 0 with respect to S_p approximately is 0.46, hence, the elasticity of output with respect to S_p is (1.0) (0.46) or 0.46. If the short run elasticity is added, the total long run elasticity with respect to P_R is between 0.5 and 0.6. The derived long run supply elasticity computed from the production functions in Appendix A and the demand equations in Chapters 5 to 9 is (0.3) (0.3) = 0.09 (operating inputs) plus (1.0) (0.6) = 0.6 (productive assets) or a total of 0.7. Based on the foregoing results, a sustained 10 percent decrease in prices received by farmers might reduce farm output from five to seven percent in the long run. The long run is more than 20 years away if the coefficient of adjustment for S_p is 0.10. Thus, the supply elasticity of 0.5 to 0.7 may not be meaningful because structural changes distort the long term price influences. But the long run supply elasticity is a useful indicator of the potential responsiveness of output to prices. It must be remembered that the computation of supply elasticities are a partial analysis and sizeable changes in output may occur due to other sources such as changes in technology. The role of technology is discussed in the following pages. Also, it is well to be mindful that the foregoing estimates of supply elasticity are subject to all the limitations of the data, techniques and judgment of the researcher.

Shifts in aggregate supply (output)

Farm output O increased over 70 percent from 1926 to 1959, or at an average compound rate of 1.71 percent per year. Equation 3 predicts a slightly greater percent increase in output during the same period. The variables in the equation provide the basis for ascertaining two general sources of the increased output: (a) changes in the input level indicated by the variables P_R/P_P and S_p and (b) changes in the output with a given level of conventional inputs indicated by the variable T'. The output-input or productivity index indicates the change in output due to weather, management and efficiency. If T' is at the 1959 value and other variables are at the 1926 value, equation 3 indicates output would have been 61 percent greater than the predicted 1926 output. Of course, we would not have needed to use this method to compute the change in output associated with T'. The productivity index was 75 in 1926, 121 in 1959, an increase of 61 percent. The equivalent results give credence to the estimational procedure. The implication is that if farm resources had remained stable, farm output would have increased 61 percent or 1.45 percent per year due to changes in productivity.

Equation 3 indicates that output was increased 16 percent from 1926 to 1959 due to investment in agriculture, indicated by S_p. If equation 2 were used to compute the portion of increased output imputed to S_p, the estimate would be higher. Equation 3 further indicates that output would have been two percent lower in 1926 if prices had been at 1959 levels; ceteris paribus. To summarize, the major portion of the increase in output from 1926 to 1959 is associated with increased productivity. Short run price influences have had little effect on the secular increase in output.

It must be emphasized that the foregoing breakdown of sources of rising output primarily explain the aggregate resource movements in response to the direct price P_R/P_P. It is not surprising that aggregate inputs increased only six percent from 1926 to 1959 since P_R/P_P decreased 12 percent. Ascribing the major portion of increased output to productivity hides many important resource substitutions. These substitutions are prompted by relative input prices (not reflected in the single price variable P_R/P_P) and by improvements in relative quality, convenience and productivity of resources. To a considerable extent the rise in productivity T' is caused by the substitution of productive fertilizer, protein feed, hybrid seed, etc., for less productive farm produced labor, power, seed and feed. Resource movements and substitutions are a more important facet of rising productivity and output than the above discussion might lead one to believe. To some extent, the substitutions are the result of long run adjustments to changing input price ratios. A more fundamental explanation of increasing output would include individual input price ratios in the supply equation. Problems of multicollinearity makes this degree of refinement impractical in this study, however.

Trends and projections

Figure 1 illustrates graphically some of the economic and technological interpretations discussed earlier. The influence of weather is apparent from the low output in 1934 and 1936 and the high output in 1959, 1960 and 1961. If

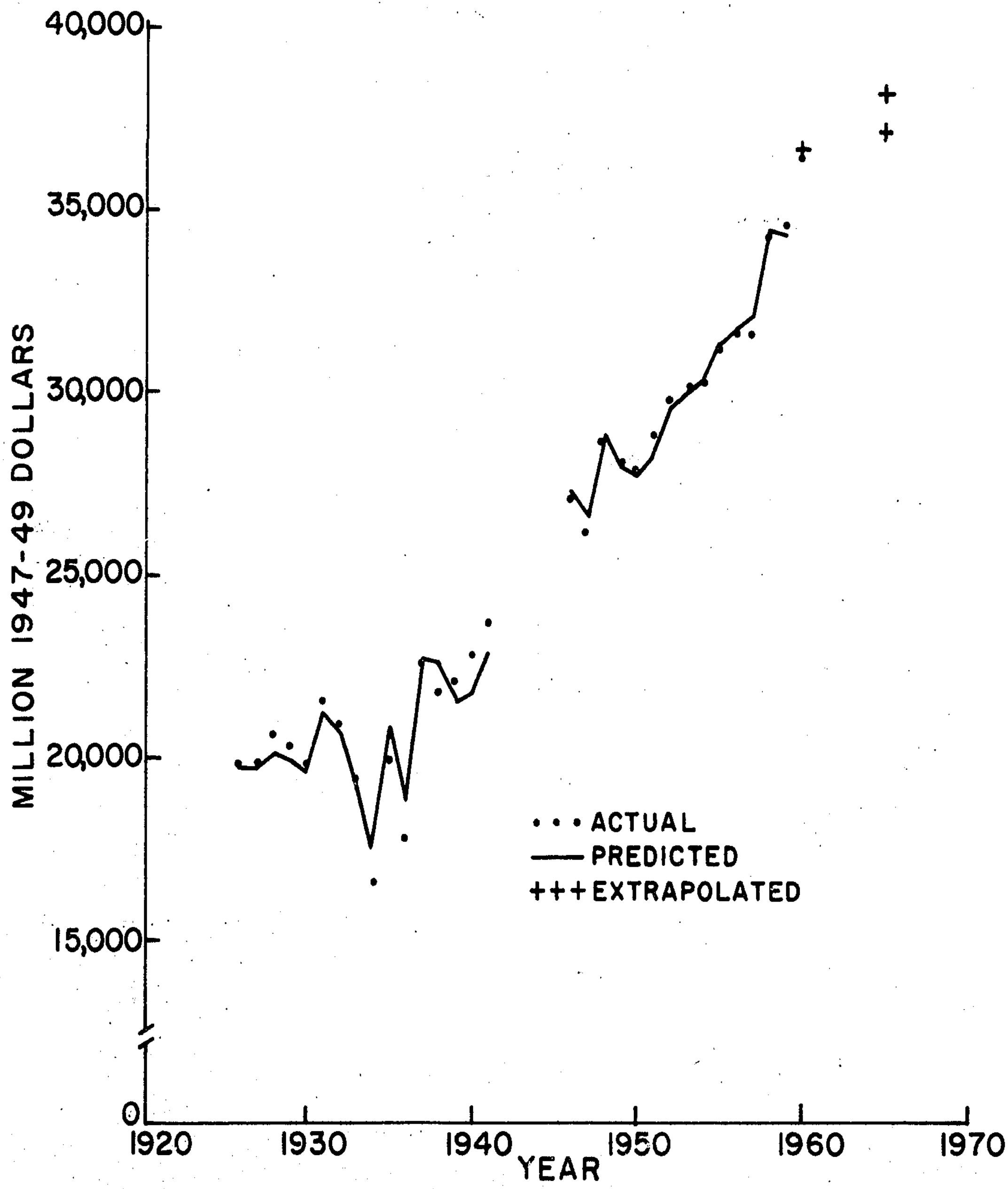

Figure 1. Trends in aggregate farm output from 1926 to 1960, showing actual values; and predicted and projected values based on equation 3

data for these years were corrected for weather, the trend in farm output would be considerably more uniform and would dramatize the unresponsiveness of output to economic stimuli. The insensitivity of short run supply to price changes is demonstrated by the low response to falling prices in the early 1930's and in recent years. Despite the fact that relative farm prices P_R/P_P gradually declined in the past decade, and in 1960 were only 73 percent of the 1947-49 average, the increase in farm output was spectacular. The increased output is attributed to better weather, long run price effects, to improved technology and farming efficiency.

Equation 3 accurately predicts the changes in output, even the recent changes. Figure 1 indicates that the prediction errors were considerably greater in the prewar than in the postwar period. The extrapolated estimate of 1960 output predicts the actual output very well. The prediction is misleading, however, since the index of productivity T' for 1960 was known and used in the extrapolation. The error might have been large if an estimated value of T' had been used. The systematic component of T' is quite predictable, but the random component, due mainly to weather, can result in rather large prediction errors when T' is unknown.

The level of output is projected to 1965 assuming prices will remain at the 1955-59 average level and that S_p will be 112.4 billion 1947-49 dollars by 1965. The estimate of S_p

is based on equation 23, Chapter 9 and is consistent with a USDA estimate (73). T' is assumed to continue increasing at the same average rate as in the 1926 to 1959 period. The lowest projected output is based on an extension of T' for six years beginning with 1959. The second, higher estimate is based on an extension of T' for five years beginning with 1960. The second estimate of T', and consequently of output, is much greater because of the large increase in T' from 1959 to 1960. The increase may be the random influence of weather, hence, the lower estimate is included. The two results indicate output will be four and seven percent above the predicted 1960 estimate by 1965.

The supply (output less change in farm inventories) functions estimated by least squares and limited information

In the short run, it is possible to increase the supply of farm products by depleting inventories of livestock and feed. The result is that the short run supply elasticity that allows for changes in inventories is somewhat greater than output elasticity. In the long run the two measures of supply elasticity could be equivalent, depending on the future output sacrificed by depletion of current production stock. In this study, we are less concerned with the short run aspects of inventory changes and give the Q_S measure of supply only a cursory examination. A single supply equation estimated by least squares from annual data from 1926 to 1959, excluding 1942 to 1945 is

$$(8)\quad Q_{St} = \underset{}{-16285} + \underset{(14.45)}{44.56}\,(P_R/P_P)_{t-1} + \underset{(50.79)}{331.91}\,S_{pt} + \underset{(44.51)}{173.13}\,T,$$

$d' = 1.08 \qquad R^2 = 0.97$

where Q_S is the predicted supply quantity, including changes in inventories. The standard errors are in parenthesis. The equation is linear in original values of variables defined earlier. The coefficients of current price $(P_R/P_P)_t$, weather W and a measure of government programs G were not significant and were excluded from the equation. The weather variable is insignificant because of its conflicting influences on farm output and inventory components of Q_S. The elasticity of Q_S with respect to P_R/P_P is 0.15; with respect to S_p is 1.21 in equation 8. If the data except T are transformed to logarithms, the resulting equation is

$$(9)\quad Q_{St} = 1.80 + \underset{(0.050)}{0.151}\,(P_R/P_P)_{t-1} + \underset{(0.21)}{1.10}\,S_{pt} + \underset{(0.00086)}{0.00344}\,T\,.$$

$d' = 1.17 \qquad R^2 = 0.96$

Equations 8 and 9 are quite comparable, both indicate that the short run elasticity of supply is 0.15. The coefficients of the variables in equations 8 and 9 are highly significant and the variables explain a high proportion of the annual variation in Q_S. The hypothesis that the residuals are not autocorrelated is rejected at the 95 percent level in equation 8 and is inconclusive in equation 9.

Because opportunities exist to adjust farm inventories and, hence, farm supply in response to current changes in demand for farm products, it was considered advisable to estimate the supply function as part of an interdependent system (cf. Chapter 2). The assumption is that the current supply is determined jointly with the markets for farm inputs and farm output. The supply equation, estimated by limited information techniques with annual data from 1926 to 1959, omitting 1942 to 1945, is

$$(10)\quad Q_S = 3100 - \underset{[-14.08]}{3427\,P_{Ot}} - \underset{[-5.41]}{1740\,P_{HLt}} + \underset{[5.15]}{1658\,P_{Rt}} - \underset{[-6.17]}{2548\,N_t} + \underset{[5.29]}{1448\,S_{pt}} + \underset{[0.71]}{2132\,G_t} + 1740\,T$$

where P_O is the price of operating inputs, P_{HL} is the wage of hired farm labor, N is farm numbers and G is an index of government programs. Other variables are defined earlier in the chapter. Prices are deflated by the implicit price deflator of the gross national product. Elasticities are given in brackets below the coefficients; standard errors are not computed. All coefficients possess the anticipated signs, but the magnitudes are too large. Because the elasticities are too large to be meaningful, we do not discuss the individual parameter estimates.

Supply Response for Two Components of Output -- Crops and Livestock

The complications from substitutions among components of output are avoided by estimating the aggregate supply function in Table 1. The conclusion that the response of output to price has not increased in the postwar period does not preclude the existence of changing responses to price for components of output. In this section, a brief analysis of the supply functions of output, yield and production units for (a) crops and (b) livestock are presented to determine the sources of output elasticity (from changes in acreage and animal units or yield).

Total output O is equal to the number of production units L multiplied by the yield per unit O/L. Tweeten and Heady (115) show that the elasticity of O with respect to price P is equal to the elasticity of L with respect to P plus the elasticity of yield O/L with respect to P if yield is independent of L. Knowledge of the response of production units and yield to price, therefore, helps to identify the source (change in yield or production units) and magnitude of the total supply elasticity. The assumption that yield is independent of acreage or livestock numbers is unrealistic, however. It is reasonable that crop yields diminish as cropland is extended to inferior lands in the short run. If prices fall, low producing cows or chickens are culled, increasing average production per remaining head. It follows that in the short run, yield and the number of production units are inversely related. This short run interdependence may be accommodated in a recursive model. The nature of the production process suggests that the "units" decision (how many acres or animals to use in production) is made before the yield decision. We assume that the current number of production units L is a function of past price P_{t-1}, other variables X_{t-1} and an error u_t, i.e.

(11) $$L_t = f(P_{t-1}, X_{t-1}, u_t) .$$

Yield per production unit O/L is a function of the number of production units, current price, other variables Y, and error w, or

(12) $$(O/L)_t = g(P_t, L'_t, Y_t, w_t) .$$

To avoid least squares bias (correlation between L_t and w_t), the predicted value of production units L' from equation 11 is inserted in equation 12. This is equivalent to making L a predetermined rather than a current endogenous variable in the supply equation 12.

The variables used in these functions, not described earlier in this chapter, are:

O_{Crt} The gross production of crops in the current year, expressed as a percent of the 1947-49 average crop output (124).

O_{Lkt} The gross production of livestock in the current year, expressed as a percent of the 1947-49 average livestock output (124).

L_{dt} Cropland used for crops in the U.S. in the current year in millions of acres (124). The variable includes acreage of land from which one or more crops are harvested, plus acreage of crop failure and summer fallow. L_d' is the predicted values of L_d from a least squares equation.

L_{kt} The current number of animal units of breeding livestock in the U.S. (124). The variable is expressed as a percent of the 1947-49 average and excludes horses and mules. L_k' is the predicted L_k from a least squares equation.

$(O/L)_{Ldt}$ Crop production per acre in the current year, expressed as a percent of the 1947-49 average (124).

$(O/L)_{Lkt}$ Livestock production per breeding unit in the current year, expressed as a percent of the 1947-49 average (124).

$(P_{Lk}/P_{Fd})_t$ The current year index of the ratio of prices received by farmers for livestock to the price paid by farmers for feed, expressed as a percent of the 1947-49 average (120). When subperiods are specified, for example 1926-41, the observations are actual annual values from 1926 to 1941, zeros from 1946 to 1959.

All variables are annual U.S. data from 1926 to 1959, excluding 1942 to 1945. Other variables are defined previously in the chapter.

Crop supply estimated by least squares

Coefficients, standard errors and elasticities are indicated for crop output O_{Cr} as a function of past year prices P_R/P_P for two subperiods, the stock of productive assets, weather and time (Table 2). The coefficients of price are 0.20 for both periods and provide no basis for rejecting the null hypothesis that the response of crop output to prices has remained unchanged between the 1926-41 and 1946-59 periods. The results indicate that the short run elasticity of crop output with respect to P_R or $-P_P$ approximately is 0.18.

Equation 14 indicates that the marginal response of acreage to prices has increased at a linear rate since 1926. The coefficient of TP_R/P_P is significant and positive. Computed at the mean of the price and time variables, the price elasticity of acreage is 0.055. The result indicates that acreage is relatively unresponsive to price changes. The long run elasticity is the short run elasticity divided by the adjustment coefficient 0.5 (one minus the coefficient of L_{dt-1}), and is twice the short run elasticity.

The response of yield $(O/L)_{Cr}$, indicated in equation 15,

Table 2. Supply functions for crop production O_{Cr}, cropland L_d and crop with annual data from 1926 to 1959, excluding 1942 to 1945; coe statistics are included[a]

Equation and dependent variable[b]	R^2	Constant	P_R/P_P t-1 (1926-59)	P_R/P_P t-1 (1926-41)	P_R/P_P t-1 (1946-59)
13 O_{Crt}					
Coefficient	0.94	-48.32		0.20	0.20
Standard error				(0.10)	(0.07)
Elasticity				0.19	0.17
14 L_{dt}					
Coefficient	0.77	252.48	-1.04		
Standard error			(0.42)		
Elasticity			0.055[c]		
15 $(O/L)_{Crt}$					
Coefficient	0.96	157.87		0.156	0.207
Standard error				(0.092)	(0.065)
Elasticity				0.150	0.173

[a]Sources and composition of the variables are discussed in the text.

[b]All equations are estimated linear in original values. Elasticiti subperiod indicated at the top of the column.

[c]The two coefficients of P_R/P_P are combined by assuming T is at the of elasticity is obtained.

n O_{Cr}, cropland L_d and crop production per acre $(O/L)_{Cr}$ estimated by least squares excluding 1942 to 1945; coefficients, standard errors (in parenthesis) and related

P_P 1 -59)	P_R/P_P t-1 (1926-41)	P_R/P_P t-1 (1946-59)	TP_R/P_P t-1	S_p t	W t	T	L_d t-1	L_d' t
	0.20	0.20		0.66	0.438	0.46		
	(0.10)	(0.07)		(0.23)	(0.067)	(0.21)		
	0.19	0.17						
04			0.030	0.49		-3.10	0.51	
42)			(0.010)	(0.24)		(1.00)	(0.13)	
055[c]			--[c]					
	0.156	0.207		0.55	0.436	0.35		-0.50
	(0.092)	(0.065)		(0.22)	(0.066)	(0.22)		(0.16)
	0.150	0.173						

s are discussed in the text.

riginal values. Elasticities are computed at the mean of the 1926-59 period or the

ned by assuming T is at the mean for the entire period. Hence, only one estimate to price appears to have increased in the postwar period. The standard error of the difference between the coefficients of price for the two periods is 0.054. The difference in the coefficients is 0.051, hence, we have no basis for rejecting the hypothesis that the yield response to price in the two periods was equal. The elasticity of yield response to price approximately is 0.16 according to equation 13. The results indicate that yield approximately is three times as price elastic as acreage (when elasticities are computed at the means of the entire period). The coefficient of the predicted current acreage L'_{dt} is negative and significant in equation 13 and indicates that greater acreage is associated with lower yields. Because of the current interaction between yield and acreage the elasticities of L_{dt} and $(O/L)_{Cr}$ with respect to price do not sum to the elasticity of crop output with respect to price. The coefficient -0.5 of L'_d indicates that a one percent decrease in current acreage is associated with a 0.12 percent increase in current yields. The result is an empirical manifestation of why acreage control programs have not been as effective as intended. If the coefficient is an accurate measure of short run acreage-yield interaction, from 10 to 15 percent more acres must be removed from production to reduce crop output a given amount than would be necessary if acreage-yield interaction were zero.

The current price variable $(P_R/P_P)_t$ was also included in the three equations in Table 2, but the coefficients were insignificant in all cases. The implication is that the effect of current year price is either too small to be detected by the small sample of observations or is overshadowed by the past year price. The prices received by farmers for crops and livestock rather than prices received for crops alone are included in the functions in Table 2 because many crops are grown for livestock feed. For these feed crops, livestock rather than crop prices are the relevant decision variable.

Livestock supply estimated by least squares

Table 3 illustrates the coefficients, standard errors and price elasticities for least squares equations expressing livestock output O_{Lk}, animal units L_k and livestock output per animal unit $(O/L)_{Lk}$. Equation 16 indicates that the elasticity of O_{Lk} with respect to past year price approximately is 0.14. The current year price coefficient is not significantly different from zero. Equation 18 provides insufficient grounds for concluding that the marginal price response in the postwar and prewar periods differ. Collinearity is less apparent, standard errors smaller, and degrees of freedom greater in equation 17 than in equation 18. Hence, equation 17 provides the more reliable estimate of the price elasticity 0.19 of livestock numbers on farms. The adjustment coefficient 0.25

Table 3. Supply functions for livestock production O_{Lk}, animal units L_k estimated by least squares with annual data from 1926 to 1959, errors (in parenthesis) and related statistics are included[a]

Equation and dependent variable[b]	R^2	d'	Constant	P_{Lk}/P_{Fd} t (1926-59)	P_{Lk}/P_{Fd} t (1926-41)
16 O_{Lkt}					
Coefficient	0.99		26.39	0.022	
Standard error				(0.047)	
Elasticity				0.0254	
17 L_{kt}					
Coefficient	0.86		50.80		
Standard error					
Elasticity					
18 L_{kt}					
Coefficient	0.87		62.96		
Standard error					
Elasticity					
19 $(O/L)_{Lk}$					
Coefficient	0.99		16.08		0.161
Standard error					(0.020)
Elasticity					0.217

[a]Sources and composition of the variables are discussed in the text.

[b]All equations are estimated linear in original values. Elasticities column.

L_k and livestock production per animal unit $(O/L)_{Lk}$
9, excluding 1942 to 1945; coefficients, standard

P_{Lk}/P_{Fd} t (1946-59)	P_{Lk}/P_{Fd} t-1 (1926-59)	P_{Lk}/P_{Fd} t-1 (1926-41)	P_{Lk}/P_{Fd} t-1 (1946-59)	S_p t	W t	T	L_k t-1	L_k' t
	0.116 (0.041) 0.135			1.16 (0.13)	0.024 (0.048)	0.68 (0.11)		
	0.165 (0.033) 0.188				-0.081 (0.037)		0.745 (0.073)	
		0.140 (0.038) 0.177	0.115 (0.050) 0.116		-0.088 (0.037)		0.59 (0.14)	
0.274 (0.032) 0.255				1.060 (0.074)		0.887 (0.069)		0.029 (0.123)

t.

ies are computed at the mean of the 1926-59 period or the subperiod indicated at the top of the (one minus the coefficient of L_{kt-1}) indicates that the long run elasticity approximately is four times as large as the short run elasticity.

The marginal response of livestock yield (livestock output per animal unit) to price increased in the postwar period according to equation 19. The t test for the difference between the coefficients, 0.161 and 0.274, is highly significant. It is interesting to note that the price elasticities 0.22 and 0.26 for the respective prewar and postwar periods are rather similar. The elasticities are computed by multiplying the price coefficients by the price-yield ratio in the respective periods. Because of marked improvements in livestock production efficiency and for other reasons, the mean of yields is much larger in the postwar period. Since relative prices have not changed appreciably, the difference in elasticities is not large despite the significant shift in marginal response between the two periods.

The insignificant coefficient of L_k' in equation 19 is consistent with the hypothesis that there is no interaction between livestock numbers and output per animal. In another formulation, the coefficient was significant and negative, however. The equations in Tables 2 and 3 are not intended to provide a definitive analysis of supply response but are intended to give a brief summary of the price response for two components of aggregate supply. The results are summarized as follows: The short run price response for all components of output are low and highly inelastic. The livestock and crop components may be more responsive than aggregate output to prices because of opportunities for substituting crops for livestock and because much feed is fed to livestock. Only the response of cropland and livestock output per animal unit to prices increased significantly in the period studied. Computed at the means, the price elasticity of cropland is lowest and of livestock yields is highest. Current prices have little influence on crop output and livestock inventories, but have a significant effect on current livestock yields.

Adjusting Farm Output

Based on the analysis in this study, it is possible to appraise the implications of various instruments for adjusting demand and supply in agriculture. Much of the discussion is oriented toward the goal of raising farm income. We do not indicate that this should be the goal of policy or what instruments must be used to attain the goal. It is for society to to determine whether parity income, parity prices, stable farm income or maximum real income to society is the relevant goal and what instruments are consistent with attaining the goal. It is possible, of course, that the most effective instruments for raising farm income may conflict with other goals such as maximum welfare for society.

Adjusting output by the price system

If the aggregate supply curve and the demand curve for farm products shift to the right at nearly the same rate, the price system can be an effective instrument for achieving the necessary adjustments. A supply curve which is vertical or negatively sloped would negate the usefulness of the price system if the shifters (non-price influences) move supply faster than demand to the right. The foregoing analysis indicates that the supply elasticity is greater than zero and, hence, does not rule out the price system as a useful mechanism for bringing necessary adjustments unless the supply curve shifts too rapidly to the right. The major shift variable of output supply is farm technology T', and of demand is population. It is interesting to note that these forces have shifted demand and supply at nearly equal average annual rates, 1.7 percent, during the postwar period. U.S. population increased 28 percent and agricultural productivity increased 27 percent from 1946 to 1960. Additional sources of product demand expansion such as increased disposable per capita income, foreign markets and improved diets have not resulted in large shifts in the demand curve in recent years and can not be expected to do so in the foreseeable future (18). If demand expands at the same rate as resource productivity T', no change in the aggregate level of conventional farm resources would be necessary. It is not surprising that aggregate inputs in farming increased only three percent from 1946 to 1960.

Improvement in agricultural prices, income and return on resources can be achieved through demand expansion or supply contraction. It is logical to focus our attention only on feasible policy alternatives. National population and farm productivity T' are not considered relevant policy instruments. Most policymakers agree that the gains to society from greater productivity are too great to be disturbed by direct action. Because the income elasticity of demand for farm products is low and for other reasons, the potential for expanding the demand for agricultural products is limited. The onus of long run agricultural adjustments falls logically on resource movements (and, consequently, output) in agriculture. The supply elasticity abstracts from the productivity index and is an indication of the output response to prices received P_R through resource adjustments.[4]

We first consider the implication of free markets for adjusting output, prices and income in agriculture. Some

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[4]The assumption is that the aggregate output-input ratio in agriculture is unaffected by prices received P_R. To test this hypothesis, the productivity index T' was regressed on relative prices P_R/P_P in agriculture. No significant relationship could be found and the hypothesis was not rejected. This test does not preclude the possibility of sensitivity of T' to changes in the relative input prices, e.g. ratios of farm labor wages to machinery price or operating input price.

studies of this type have been made (18, 105, 117) but have lacked adequate knowledge of the supply response. A study of the ramifications of free markets is a major research project in itself. The principal purpose of this study is to estimate supply parameters rather than to trace the exact implications of free markets. But to illustrate the meaning of the supply elasticities found in this study and to illustrate broadly some of the adjustments that would occur, a free market model is simulated using elements of the existing situation. The assumptions of the model are: (a) current agricultural output is predetermined by past prices (supply) and current price is determined by current output (demand), (b) the average price flexibility of product demand in the short run at the farm level is -4.0 (price elasticity is -0.25),[5] (c) that five to

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[5]A recursive model is assumed in Table 4. The model is equivalent to assuming that the current supply quantity (output) is a function of past prices in the supply equation linear in logarithms. Similarly, the current price is a function of the predetermined current quantity in a single least squares product demand equation linear in logarithms. The coefficient of the quantity variable in the demand equation is the constant price flexibility. It is not strictly correct to assume that the inverse is the price elasticity of demand. That is, the price flexibility generally is defined as the coefficient of quantity when price is the dependent variable. Price elasticity of demand generally is defined as the coefficient of price when quantity is the dependent variable. The two concepts are equivalent only if there is no error in the model or if the assumptions are correct underlying the limited information technique, which is independent of the direction of normalization. The product demand function was not estimated in this study. For a summary of several estimates of the price elasticity of demand for product aggregates in agriculture, see Brandow (17, pp. 19, 50).

10 percent of all agricultural output is being diverted from price setting markets by government accumulation of surplus, export and consumer subsidies or resource restrictions (cf. 105, p. 6; 117, p. 20), (d) that non-price influences shifting supply to the right are offset by demand expansion, (e) that input prices in aggregate will remain stable, that existing stocks will not be placed on the market, that prices will be determined by current output, and (f) that markets for farm products (outside of government restrictions, etc.) are now in equilibrium. The estimated elasticity of aggregate supply (output) is 0.10 in the short run, 0.15 in the intermediate run. There would be obvious advantages in considering the output responses for several categories of farm output. For purposes of this study, however, it is felt that many of these advantages would be lost because of the elusive substitution possibilities among components of farm output.

The movements of farm prices, output and gross income are indicated in Table 4. The first example assumes that relaxing of government restrictions would increase marketing of farm products five percent above the initial level. The five percent increase in output decreases farm prices from the initial index of 100 to 80 in year 1, or 20 percent. Because output is greater, gross income falls by a smaller percentage, 16 percent. Assuming production expenses remain at current levels, net income would fall more than 40 percent

Table 4. Simulated adjustments of output, price and gross income to free markets based on supply (output) elasticities estimated in this study[a]

	Year 0	1	2	3	4
Cumulative supply elasticity	0	0	0.10	0.13	0.15
Example 1 -- five percent increase in output					
Output O	100.0	105.0	102.9	102.6	102.4
Price P_R	100.0	80.0	88.4	89.6	90.4
Gross income	100.0	84.0	91.0	91.9	92.6
Example 2 -- ten percent increase in output					
Output O	100.0	110.0	105.6	104.9	104.5
Price P_R	100.0	60.0	77.6	80.4	82.0
Gross income	100.0	66.0	81.9	84.3	85.7

[a]The short run supply elasticity is 0.10, the intermediate run elasticity 0.15. Other assumptions are discussed in the text.

in year 1.[6] The supply response to low prices in year 1 becomes apparent in year 2. For each 10 percent drop in prices, farmers decrease output one percent. Hence, output falls from 105 in year 1 to 103 in year 2. The reduction of output in year 2 arises primarily from the reduction in operat-

[6]Realized gross farm income currently is approximately 38 billion dollars, production expenses 26 billion dollars and net income 12 billion dollars. If gross income fell to 84 percent of the current level as in example 1, Table 4, and production expenses remained at the current level, net income would be 32 - 26 = 6 billion dollars. Net income would fall from 12 billion to 6 billion dollars, or 50 percent below the initial level.

ing inputs such as fertilizer, protein feed, etc. After year 2, supply adjustments depend primarily on adjustments in durable inputs. The potential long run adjustment of output is large from durable inputs such as irrigation equipment, drainage and livestock inventories (the long run price elasticity is 0.6). The annual or "marginal" adjustment is small, however, and is only 0.03 from year 2 to year 3. Since P_R is 88.4 in year 2, or 11.6 percent below the initial price, the output adjustment is (11.6) (0.03) or 0.3. Output in year 3 is therefore 102.9 - 0.3 = 102.6. The "excess" supply is 2.6 percent, hence, P_R is (4) (2.6) or 10.4 percent below the equilibrium or initial price in year 3 according to the assumptions in example 1. Gross income is (102.6) (89.6) or and index of 91.9 in year 3. Net income is not shown but also is improved, not only because gross income is higher, but also because expenses are lower in year 3. It is apparent that the rate of adjustment of prices, output and income toward initial levels are slowing considerably by year 4. Prices and incomes remain considerably below initial levels but are improving gradually. Adjustments become small, therefore, the adjustments after year 4 are not illustrated.

Because removing government restrictions is expected to increase marketings between five and 10 percent, example 2 is also included in Table 4. A 10 percent increase in output depresses farm prices 40 percent. Gross income decreases from an index of 100 in year 0 to an index of 66 in year 1. Farm inputs have not yet responded to falling prices and production expenses remain at the initial level in year 1 according to the assumptions of the model. Actual farm expenses currently are 65 to 70 percent of realized gross farm income. A drop of one-third in gross farm income, depicted in year 1 of example 2, would leave farmers with little net income. Because net income is required for household and other expenditures, a serious farm financial crisis would result. The 40 percent decrease in farm prices decreases output four percent from year 1 to year 2. This adjustment of output from 110 to 105.6 improves farm prices and income, but the respective indices are only 77.6 and 81.9 percent of the initial levels in year 2. The rate of adjustment of output to low prices is slow in years 3 and 4. In year 4, P_R is 82 percent of the initial price and gross income is 86 percent of the initial income.

As indicated earlier, Table 4 is presented to illustrate (a) the adjustment to free markets and (b) the interpretation of the parameters estimated in this study. The recursive nature of the adjustment process is apparent. It is not possible to conclude because the intermediate run elasticity is 0.15 that a 40 percent drop in P_R (from an index of 100 to 60 in example 2) will decrease output (40) (0.15) = 6 percent in four years. To decrease output six percent, the 40 percent fall in price must be <u>sustained each year</u>. Because some adjustment occurred before year 4, P_R was above the year 1 index in years 2 and 3 (was less than 40 percent below the initial level). Thus, output declined to an index of 104.5 rather than to 103.4 (110 less six percent of 110) in example 2. These results indicate that the supply elasticity may be a misleading indication of adjustment potential. Supply elasticity estimates indicate that output is decreased six percent in approximately 25 years by a sustained 10 percent drop in P_R. But because of the recursive nature of adjustments, indicated in Table 4, the initial drop in price is not sustained, but gradually rises. The result is that less adjustment is made in a given period than the supply elasticity, defined in terms of a sustained price, might lead one to expect.

The benefits of a supply response greater than zero are apparent from Table 4. If the elasticity of supply were zero, the indices of price and income would fall to 60 and 66, respectively, in example 2 and remain at that level each year thereafter. The fact that gross income recovered nearly 30 percent from year 1 to year 4 in example 2 indicates that supply response can not be omitted in studies of free markets without introducing large errors.

For <u>gross</u> income per farm worker to be improved, the respective number of workers would need to decline approximately seven and 15 percent in examples 1 and 2. In Chapter 10, a sustained 35 percent fall in relative (residual) farm income per worker was found to reduce the number of workers 10 percent in four to six years. We cannot determine the decline in residual income to labor from Table 4 without making assumptions about expenditures. Based on the assumptions that a one percent decline in P_R decreases residual income two percent (cf. Appendix B), the average decline of net income from the initial value is 25 percent in example 1. If the elasticity of response of labor to income is 0.35 in four years (cf. Chapter 10), the decline in labor numbers is (25) (0.35) = 9 percent. P_R is 90.4 or 9.6 percent below initial levels in year 4 (example 1). Based on the assumed two percent average drop in net income for each one percent decrement of P_R below equilibrium, total net income would be (2.0) (9.6) = 19 percent below the initial level in year 4. Thus, the fact that net income has fallen more than employment suggests that per worker incomes would be considerably below initial levels by year 4. The example is crude, of course, and is only a very rough measure of the effect of free markets on per worker incomes. Over a longer period, income per worker would continue to improve but at a very slow rate.

One may question whether the results in Table 4 underestimate or overestimate the ability of free prices to adjust incomes in agriculture. Based on the previous chapters, the assumption that non-price influences shifting supply to the right will be offset by demand expansion may not be realistic. Rapid recent increases in farming efficiency indicate that this source alone may meet or exceed the expanding demand without increasing the application of conventional inputs. Restraining the level of conventional inputs places a great strain on the price system. The input demand functions estimated in this study suggest that there are strong non-price influences which increase inputs with high production elasticities. These influences, discussed in the foregoing chapters, are likely to continue in the future. In some instances the forces other than price overshadow the price effects. Even drastic reductions in farm prices may not be able to offset the input increasing effects of these forces. It follows that Table 4 may present an overly optimistic view of the ability of the price system to cope with the resource and income adjustments needed in agriculture.[7]

Some implications of direct supports for farm prices P_R without controls or diversionary purchases are apparent from

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[7]Another source of declining net income and need for resource adjustment is the increasing prices paid by farmers for inputs. Prices of some resources (e.g. labor) increase more than others (e.g. operating inputs), but the general price trend is upward. From 1946 to 1960, prices paid by farmers for items used in production, including interest, taxes and wage rates, increased 44 percent. Rising input prices like falling output prices depress net farm income and place an additional burden on the price mechanism to bring needed adjustments.

the estimated supply elasticity. The output increasing effect of price supports acts against the intended purpose. Assume that direct price supports increase P_R 10 percent. Since the short run supply elasticity is 0.10, output is increased one percent in two years. If price flexibility is -4.0, the one percent increase in output tends to decrease P_R four percent. Hence, the net "real" support price is the original 10 percent increase minus four percent, or six percent. In the intermediate run, the supply elasticity is 0.15, hence, output is 1.5 percent greater. The net real increase in P_R would be only four percent. It is apparent that because of the inelastic demand for farm products, the intended price and income benefits to farmers would soon be dissipated unless farm output is controlled.

Adjusting output by changing inputs of individual resources

Another method of reducing output in agriculture is by controlling inputs either by price restrictions and incentives or by direct controls on inputs. Unfortunately, a conflict exists between resource adjustments to encourage economic efficiency and to cut production (raise product prices). From the standpoint of economic efficiency, the desired adjustments should encourage outmovement of resources which have a higher marginal value product in alternative uses. The results in Appendix A indicate that the marginal value product of labor in agriculture is nearly zero. If national unemployment is not too high, the returns from shifting a unit of labor from agriculture to other areas may be large according to Chapter 10. But because the mobility of labor is not highly responsive to price, and outmovement of each unit has little effect on farm production, the means for decreasing output (increasing total income) have centered on other farm resources, principally on operating inputs and real estate. Because the production elasticity of operating inputs is quite high (approximately 0.3 according to the equations in Appendix A) and the short run demand elasticity is sizeable (found to be approximately -0.6 in Chapter 5), a tax on operating inputs would bring quick results. A 20 percent reduction in operating inputs (fertilizer, protein feeds, etc.) would reduce output six percent. It would be necessary to increase the price of operating inputs 30 to 35 percent by a tax or other means to achieve the desired reduction in output. The analysis in Chapter 5 indicates that the reduction could be effected in the short run, approximately two years. This does not necessarily mean that the problem of low returns in agriculture would be solved. Higher input prices would mean greater expenses although the proceeds of the tax might be returned to farmers. Also, reduced output would raise farm output price P_R and encourage additional application of fertilizer and other inputs and would dampen the first benefits of the program. Many of the short term gains, therefore, would be lost in the long run.

Direct rationing or restricting operating inputs by 20 percent would be more effective than controlling input price and would not have the side effects of increasing operating expenses and expanded use of operating inputs as product prices increase. Because of opportunities for substituting other inputs for operating inputs, again some of the short run benefits would be lost in the long run.

The other major resource which has an important impact on farm output is real estate, including buildings, land and improvements. The resource quality is heterogeneous. The production elasticity, approximately 0.5 in Appendix A, refers to an "average unit" at the margin. An average unit could be defined as a complete farm (less operating inputs, machinery, livestock and feed inventories) in an area of average national productivity. It is apparent that one of the most effective ways of reducing farm output would be to remove whole farms from production. To reduce output five percent, it would be necessary to reduce the aggregate real estate input 10 percent. Since cropland used for crops is now approximately 360 million acreage, 36 million average crop acres including real estate improvements would need to be taken out of production to lower output five percent according to the results of this study. The foregoing statements apply to average land at the margin. There is considerable enthusiasm for converting farm land to recreational uses. The marginal value of much of this land is lower in farming than in alternatives such as wild life preserves, parks, etc. Converting such land which has a low product in agriculture to other uses is consistent with economic efficiency and societal welfare but cannot be expected to reduce output appreciably or close the gap between returns to labor and capital in the farm and non-farm sectors. A land retirement program will be effective only to the extent that productive real estate is converted to alternative uses (or non-use).[8]

It is well to emphasize again that the above statements do not imply what should be done, but only point up the implications of various alternatives.

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[8]Some possible methods of removing real estate from production are rural zoning, taxes or direct payments. Because real estate has few alternative uses outside agriculture in most instances, the level of use is unresponsive to land price. Land price is a residual claimant, and tends to reflect the capitalized net return on land. A direct payment greater than the residual return would move land out of production. It is interesting to note that a gradual program of direct payments for taking land out of production would become increasingly more costly. The more effective the program in reducing output and increasing income, the greater the tendency for land values and residual income to land to increase. The result would be greater costs for removing land from production as the program progressed.

Summary of Empirical Results

The supply function in agriculture depends on resource mobility and productivity. The supply elasticity was estimated from the input demand equations in Chapters 5 to 9, the production functions in Appendix A and direct supply equations in Chapter 11. The results indicate that the output supply elasticity with respect to prices received is 0.10 in one or two years, 0.15 in four years and 0.6 in more than 20 years. If inventory changes are included with output, the short run (one or two year) supply elasticity with respect to prices received by farmers is higher, approximately 0.15.

The supply response was divided into four categories in Tables 2 and 3: (a) cropland acres, (b) crop output per cropland acre, (c) animal units of livestock, and (d) livestock output per animal unit. The results indicated that the response of acres (a) to prices is lowest, of livestock yield (d) to prices is highest of the categories studied. The elasticity of crop output per acre (b) and of livestock numbers (c) with respect to prices ranks between the foregoing extremes. The price response of these latter components (b) and (c) have not increased significantly in the period studied, 1926 to 1959, but the response of acres and livestock yields to price appears to be increasing. The influence of current price was only significant in determining livestock yields. The potential for increasing livestock output per animal unit in the current year is relatively high -- the price elasticity with respect to the livestock-feed price ratio was 0.26. For other components of total output, past year prices appeared to be more important than current year prices. For all categories which were analyzed, the short run supply was highly inelastic.

Total farm output increased 71 percent from 1926 to 1959. Because total inputs in agriculture increased only six percent in the 33 year period, rising productivity must explain most of the increase in farm output. This conclusion obscures some of the important adjustments taking place in the resource structure. To a considerable extent, the rising productivity reflects the substitution of productive non-farm inputs such as fertilizer for less productive farm produced resources.

Based on the assumptions that (a) investment in productive assets will be 112.4 billion 1947-49 dollars by 1965, (b) prices will remain at the 1955-59 average level, and (c) productivity will continue to increase at the average rate of the 1926-59 period from 1960 to 1965, the projected output for 1965 is seven percent above the predicted 1960 output.

The supply coefficients estimated in this study provided the basis for a simulated model of free markets in agriculture. Based on several assumptions discussed in the text, the trend in output, price and income are traced for four years. If farm marketings are increased five percent by removing government restrictions, prices received by farmers are expected to be 10 percent below the initial price by the fourth year. Gross income is estimated to fall below the initial level by 16 percent the first year and seven percent the fourth year. Net income declines even further the first year, approximately 50 percent. Adjustments after year 4 become very small; recovery of the initial income level would require many years according to the results of this study. Introduction of the family labor function into the analysis also indicates that the net income per worker would be lower than the initial level by year 4, and improvements thereafter would be slow. The results indicate that considerable farm income would be sacrificed by a return to free prices. Whether gains in "freedom" more than compensate for the loss in income must be determined by farmers and policymakers. The analysis may overestimate the level of farm prices and incomes under free markets. Because influences other than price tend to increase inputs of highly productive resources in agriculture, the price mechanism may not restrain output to the extent indicated in Table 4. The result would be lower prices (received) and income by farmers than indicated.

Adjustments of individual resources also provide opportunities for decreasing output and increasing returns in agriculture. From the standpoint of economic efficiency and maximum societal welfare, resources with higher returns in non-farm uses such as marginal labor and land suited for recreation should be shifted to non-agricultural uses. But the most effective measures to control output must concentrate on the productive operating and real estate resources. The results indicate that a 30 to 35 percent increase in the relative price of operating inputs would reduce output six percent in the short run. In the long run, the operating input price increase would be less effective because of higher farm product prices and possibilities for substitution among inputs. According to the analysis, it is necessary to reduce real estate input 12 percent to reduce output six percent. The 12 percent reduction in real estate input would require retirement of over 40 million average cropland acres (with improvements) from production. The implications of other policy instruments also may be evaluated from the coefficients derived in this study.

CHAPTER 12: CONCLUSIONS

Results of the study have been discussed pertaining to four specific objectives, i.e. estimating structural coefficients in demand and supply equations, projecting future quantities, determining aggregate product supply and implications of policy alternatives. The general impression is that the analysis was successful, although shortcomings can be cited. Many of the results are summarized adequately in the respective chapters and need not be discussed again. Some implications of the study logically could not be summarized in any one chapter. For example, estimates relating to a fifth objective, determining the interrelationships of variables in the farm and non-farm sector were presented in several chapters, and a general summary is necessary. The purpose in Chapter 12 is to: (a) compare general empirical results among chapters, (b) present a critique of statistical methods and models, and (c) summarize quantitative relationships between the farm and non-farm sectors.

Input Demand Functions

Elasticities

Demand elasticities differ markedly over time and among inputs. As expected, annual investment in farm durables such as machinery and building improvements is most sensitive to price in the short run. The short run price elasticity of demand for these items approximately is unitary. The "average" own-price elasticity of operating inputs is nearly -0.6. The short run price elasticity for components of operating inputs varies from nearly zero for seed to unity for building repairs. Of the major input groups, durable stocks and labor are least responsive to prices in the short run. The price elasticity of building and machinery stocks or labor with respect to own-price (or prices received by farmers) approximately is -0.1 in the one or two years.

The magnitudes of the elasticities are larger, but the relative positions remain quite similar, when the short run (one or two years) is extended to the intermediate run (three or four years). In the long run, which may be over 20 years, the short run pattern is upset. Stocks as well as annual investment in buildings and machinery are responsive to price when the price rise is sustained for several years -- the elasticity is 2.0 or greater with respect to prices received. Demand for operating inputs and hired labor is inelastic in the long run. To summarize, the price elasticity of demand for durables is highest and for farm labor is lowest in the long run.

Derived input demand and production elasticities and direct estimates of aggregate supply functions indicate the response of farm output to price. The short run supply elasticity, imputed primarily from operating inputs, is 0.10. The intermediate and long run elasticities, imputed to a large extent from durable assets, are 0.15 and 0.6, respectively. More than 20 years are required to make the long run adjustments according to the results of this study.

Four components of supply briefly were analyzed: acreage, animal units, crop yield and livestock yield. The supply response of livestock yield in the current year is relatively high and is increasing -- the price elasticity is 0.2 to 0.3. Other components of supply are more responsive to past than current year price. As expected, the response of cropland acreage to price is lowest, but is increasing.

The analysis indicates that farm labor has little influence on the supply of farm products. Labor mobility influences income per worker, however. According to the results in Chapter 10, a sustained 10 percent drop in farm income reduces employment of family workers up to 3.5 percent in approximately five years.

There is a basis for criticizing our emphasis on elasticities rather than on marginal response (coefficients in equations linear in original values). Some of the disadvantages of working with elasticities rather than marginal response (slope of demand or supply curve) were discussed in Chapter 11. The elasticities may hide changes in the marginal response to price, particularly in industries characterized by rapid technological change. The slope of the supply curve may have increased appreciably over a given period, but because a greater quantity is supplied at a given price, the elasticity may be constant or decrease. The elasticity is independent of the unit of measure but not of the base. Depending on whether the elasticity is computed at the mean of the postwar or prewar period, quite different results may be obtained. To avoid misinterpretation in Chapter 11, both the marginal response and elasticities are included in Tables 2 and 3. In other sections of this study, elasticities are emphasized. The reason is that it is not very enlightening to state that aggregate farm output will increase 10 billion 1947-49 dollars if prices received by farmers increase one 1947-49 index point.

Substitutions among inputs

The empirical demand equations provide meaningful estimates of the response of input demand quantities to own-price and product price. Because input prices tend to be correlated through time, time series statistical analysis do not provide detailed estimates of market substitutions among inputs. The extent of bias arising from failure to adequately specify the substitution effects in the demand functions is unknown. Some of the techniques used in the study reduce the extent of bias. For example, specification of beginning year inventories of durable assets S_p in the demand functions for operating inputs reduces the number of variables in the equation. The relation of operating input purchases to variables explaining durable assets is found by inserting price and other variables explaining S_p into the estimated operating input demand equation. Use of abbreviated forms such as income equations reduces the required number of price variables and specification error. Additional regressions of income on prices and other variables permit isolation of more detailed substitution and other effects.

Graphic analysis and estimated demand equations indicate sources of historic trends in input purchases. The input demand equations show that the historic trends cannot be attributed entirely to declining own-price relative to output price. Much of the secular rise in demand for machinery and operating inputs is associated with other input prices, convenience, improvements in input quality and other variables not specifically identified in the demand equations. Graphic analysis illustrates that major shifts in demand quantities (except real estate) are consistent with relative prices. Rising machinery inventories cannot be explained by trends in machinery prices relative to prices received by farmers. But the graphic analysis indicates that the growth in machinery inventories is consistent with complementarity with operating inputs and substitutability with labor. That is, the prices of operating inputs have decreased, of labor have increased, relative to machinery prices.

Trends and projections

Some of the major structural changes taking place in agriculture in the last three decades are apparent from changes in the inputs of major agricultural resources. From 1926 to 1959 inputs of operating items increased 200 percent, durable capital (stock of all farm machinery and buildings) increased 60 percent, cropland acreage remained nearly constant and family (or total) labor employment declined 43 percent. Projections for the future are quite consistent with these past trends. By 1965, annual inputs of operating items are projected to be approximately 10 percent greater than in 1960. The projected increase in some components of operating inputs such as fertilizer are expected to be even greater. Based on assumptions discussed in Chapter 9, stocks of durables (machinery and buildings) are expected to be five percent above the 1960 level by 1965.

The rapid outmovement of labor is expected to continue. The number of family workers in agriculture is projected to be 14 percent below the 1960 number by 1965. Based on these results, there are few signs of a slowdown in the major structural changes occurring in agriculture. Standard errors of the projections were not computed. It is expected that the errors would be large for several years in advance, however.

Interaction between the Farm and Non-Farm Sectors

The functions estimated in this study provide quantitative measures of the influence of non-farm variables such as wage rates, unemployment, etc. on the farm economy. The input supply equations, estimated by limited information, indicate the relationship between farm input prices and non-farm wages and prices. Because the input supply equations contain few variables, complications caused by multicollinearity may not be as large as in other simultaneous equations estimated in this study. Nevertheless, the coefficients should be interpreted cautiously. The limited information equations indicate that a one percent increase in non-farm wage rates is associated with a one percent increase in operating input prices, and with a 0.6 percent increase in farm wage rates. Similarly, a one percent increase in the wholesale price of iron and steel tends to be reflected in a one percent increase in farm machinery prices.

These results are somewhat consistent with the postwar trends in prices paid by farmers and non-farm wage rates. From 1946 to 1960, annual wage rates per factory worker increased 107 percent, or five percent per year. In the same period, prices paid by farmers for items used in production, interest, taxes and wage rates increased 44 percent, or 2.6 percent per year. The relationship of non-farm wage rates to input prices has important implications for farm expenses and income. On the average a 2.6 percent increase in input prices tends to be reflected in a similar percentage increase in farm operating expenses. Operating expenses currently are approximately one-half gross farm income. Hence, a given increase in operating expenses tends to decrease net income (after paying operating expenses) a similar percentage. To some extent, wage increases are reflected in higher consumer incomes and greater demand for farm products. But the increase does not compensate for higher farm expenses. Prices received by farmers were nearly the same level in 1960 as in 1946. These results highlight the close relationship between farm input prices and non-farm variables. Labor contracts providing for wage increases clearly are related to production expenses in agriculture. The wage-price spiral in non-farm industries has expense and income repercussions on the farm economy.

The influence of unemployment on farm labor mobility is apparent from Chapter 10. The results indicate that the tendency for a given increase in non-farm income to encourage outmovement of family workers from agriculture gradually diminishes as unemployment rises. Response of workers to non-farm income is negligible when unemployment reaches

20 percent. The elasticity of family labor numbers in agriculture with respect to non-farm income is as high as 0.2 when unemployment is near zero and is zero when unemployment is 20 percent.

Other variables which have some elements exogenous to the farm sector are national disposable income, interest rates and government programs. The demand for farm products was not estimated in this analysis, but previous studies indicate that the average income elasticity of demand is 0.2 or 0.3 (42, p. 109). When economic conditions in the non-farm economy are depressed, national disposable income tends to fall faster than wage rates because of the institutionalized wage structure. That is, the depressed economic conditions (reduced disposable income) are reflected in unemployed workers rather than in lower wage rates. The result is that prices received by farmers tend to fall more than prices paid in agriculture.

If interest rates and government programs exert a significant influence on input purchases in agriculture, it was not apparent from the study. Coefficients of interest variable either had the wrong sign or were insignificant in the investment equations. The coefficients of a dummy variable, intended to reflect the direct influence of acreage restrictions and other government programs on input purchases, were significant in some instances. The number of significant variables was no greater than anticipated when sampling from a population in which the coefficient is zero. Insignificance of the rather crude dummy variable does not preclude a direct influence of government actions on input purchases through price and income effects, however. The impact of a government program, which alters prices by a given amount, on inputs and output can be judged from the estimated price elasticities.

Table 1 illustrates some of the concepts discussed previously. Consecutive years are selected to avoid structural changes connected with comparisons between distant periods.

Table 1. Comparison of actual changes in farm and non-farm variables between selected years of economic expansion and recession[a]

	Recession (1948-49) Percentage change	Expansion (1950-51) Percentage change
Non-farm variables		
Annual wage rates per factory worker	1.46	9.08
Unemployment	2.10	-2.00
Disposable income per capita	-1.47	7.67
Farm variables		
Index of weather	-20.33	-1.96
Prices paid by farmers	3.38	10.61
Prices received by farmers	-13.21	17.89
Total net income	-14.12	14.96
Number of farm workers	-3.85	-3.83
Net income per farm worker	-9.28	17.71

[a]Data from USDA (120, 121, 124) and other sources (30, 108).

In the recession, factory wages increased 1.5 percent, prices paid by farmers increased 3.38 percent. Despite the rise in non-farm wage rates, disposable income per capita declined 1.5 percent and farm prices received fell 13 percent. Net farm income declined 14 percent due to low prices and also to poor weather.

Wages and income improved appreciably in the non-farm sector from 1950 to 1951. Changes in these variables are reflected in higher farm prices received and paid by farmers. Despite changes in unemployment in the national economy, the rate of outmovement of farm workers was about 3.8 percent in each period. The reasons may be that farm labor is unresponsive to relative income in the short run, and because changes in income are correlated. The fact that economic conditions are correlated in the farm and non-farm sectors impedes the effectiveness of the price mechanism from bringing needed resource adjustments. The sample is small and certain qualifications are necessary. Relations between farm and non-farm variables are obscured by changes in weather and supply between periods. The results are consistent with some of the coefficients discussed earlier, however.

Critique of the Statistical Procedures

Single and simultaneous equations

The results from the single least squares equations are more acceptable than those from the more "refined" limited information simultaneous equations. The number of anomalous coefficients are fewer in functions estimated by ordinary least squares. The single equations present a consistently meaningful and precise pattern of estimated coefficients. The magnitudes of the coefficients in equations estimated by limited information appear to be unusually large. Perhaps too little and too much is attempted with the simultaneous model. Too much is attempted by assuming a higher degree of interdependence in the system than is necessary. Too little is attempted because many separate, smaller interdependent models might be fitted for market subsystems. Additional "experimentation" with small subsystems, undoubtedly, would provide more realistic coefficients in the limited information model than were obtained by the technique in this study. The interdependent model may be particularly appropriate for hired farm labor markets and for livestock and feed inventory markets.

The less acceptable results of the limited information model to some degree are a function of the large computational requirements. Lack of flexibility of the approach hinders taking advantage of new information as it becomes available. Based on additional replicated studies, more accurate appraisal of the causal structure and consequent degree of refinements needed in statistical models will become more clear. One can only conclude on the basis of this study that single equations emphasizing the recursive production and decision process are a satisfactory stochastic model of the agricultural resource structure.

Distributed lag models

The study indicates some form of dynamic distributed lag (adjustment or expectation) is necessary for expressing demand for all categories of agricultural inputs. For operating inputs, prices lagged no more than one year appear to be appropriate. Demand for durables (investment) is expressed most adequately by combining simple, naive expectation variables with adjustment models of the Koyck-Nerlove type. The distributed lag adjustment model seems to complete the specification of the family labor function. Particular success is obtained by oversimplifying the demand and supply functions into an abbreviated form. That is, a single variable is used to represent expectations in the demand functions for durable inputs. Similarly, a single variable representing durable stock is used in the operating input and product supply equations. From knowledge of the process by which these single variables are generated (e.g. from the investment function), a great deal can be learned of the long run process generating operating input demand or product supply in agriculture. In many instances, this procedure appears to be more useful than the Koyck-Nerlove models. The Koyck-Nerlove approach is based on equal rates of adjustment of the dependent variable to each independent variable. The abbreviated form provides more flexibility in rates of adjustment to different underlying influences.

There is a premium on simplicity in positivistic, stochastic models. The simple, abbreviated least squares equations of a monocausal or recursive type are applicable in a large number of instances. To summarize, there is no clear verdict for any one model or technique to be used in all instances. This conclusion is not very startling, and is what might be expected.

Other statistical considerations

High values of the multiple coefficient of determination R^2 are obtained in most of the equations estimated in this study. *Ceteris paribus*, some advantages of a high R^2 are increased confidence in the specification, less autocorrelation in the residuals and least squares bias, and more precise predictions and parameter estimates. A major source of the high R^2's is the easily predictable (and undefinable) influences associated with trend variables. The high aggregation averaged out some of the variation found in the micro variables. Hence, the high R^2 is a misleading indicator of what is known of the resource structure.

Aggregation procedures and data reliability are discussed in detail in Chapter 4. It is well to stress again that the implications of the study are subject to the reliability of the data as well as to the adequacy of the techniques. Perhaps too much emphasis is on significant results and structural relationships and not enough on the reliability of the underlying data. The independent variables are assumed to be measured without error -- but all the data contain errors. The extent of consequent bias in the coefficients is difficult to judge. Additional investigation is required to determine the degree of errors introduced into quantity, price and other variables by changes in input quality, aggregation procedures, etc.

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APPENDIX A: AGGREGATE PRODUCTION FUNCTION FOR AGRICULTURE

Tables 1 and 2 contain six aggregate average production functions for U. S. agriculture estimated by least squares from times series. The variables included in Table 1 are defined as follows:

O — The dependent variable is the production of crops and livestock on U. S. farms during the current calendar year for eventual human consumption (4). The measure is corrected for intermediate use of resources such as farm produced power, for feed fed to livestock, etc.

Q'_{RE} — Real estate input, measured as the constant dollar value of annual services required to maintain the input at the current level (4). The variable includes interest, depreciation, damage and repairs, and taxes on real estate, i.e. land and buildings. Taxes are included to reflect the social input.

Q_D — Input of durables, measured as the services, required to maintain the input at the current level (4). The variable includes interest, depreciation, insurance and taxes on productive machinery, livestock, feed, horse and mule inventories plus license fees on the productive motor vehicles. The repairs, fuel and lubrication requirements for farm machinery are included in operating inputs Q'_O, not in Q_D.

Q_{TL} Total farm employment in 1000 workers, including hired and family laborers during the current calendar year (30, 118).

Q_O' Inputs of operating items, including fuel, oil and repairs for machinery, electricity, blacksmith repairs and hardware expenses, binding materials, dairy supplies, ginning costs, the non-farm share of feed, seed and livestock purchases, fertilizers and, finally, interest on operating capital (4). It differs from the quantity Q_O in Chapter 5 by excluding building repairs and including the interest on operating capital.

W Stalling's index of the effect of weather on farm output in the current year (108, 124). Indices for 1958 and 1959 were not available from the original source, but were estimated from the deviations from a linear yield trend.

T Time, an index composed of the last two digits of the current year. (Other variables are in logarithms, but time is in original values.)

All of the foregoing variables except T are logarithms of national aggregates for the current calendar year from 1926 to 1959. Quantities other than Q_{FL} are aggregated by 1935-39 prices prior to 1940, by 1947-49 prices after 1940. After aggregation, the variable is expressed as the "physical

Table 1. Average aggregate production functions for U. S. agriculture estimated by least squares with annual data from 1926 to 1959; elasticities of production, standard errors (in parenthesis) and related statistics are included[a]

Equation	R^2 and $\bar{R}^2$	d'[b]	Constant	Q_{RE}	Q_D	Q_{TL}	Q'_O	W	T
1	0.98 0.97	1.95	0.066	0.47 (0.49)	0.038 (0.127)	0.16 (0.22)	0.28 (0.10)	0.345 (0.062)	0.0024 (0.0015)
2	0.98 0.98	1.89	1.13	0.40 (0.18)			0.294 (0.051)	0.331 (0.055)	0.0014 (0.0010)
3	0.98 0.97	1.78	0.69	0.50 (0.33)	-0.024 (0.108)		0.373 (0.048)	0.309 (0.058)	
4	0.98 0.97	1.79	0.58	0.44 (0.18)			0.363 (0.015)	0.313 (0.055)	

[a]See text for source and composition of variables. All variables, except T, are in logarithms of original observations.

[b]The Durbin-Watson autocorrelation statistic d'.

Table 2. Average aggregate production function for U. S. agriculture estimated per unit of farm labor by least squares from annual data; elasticities of production, standard errors (in parenthesis) and related statistics are included[a]

Equation	Time period	R^2 and $\bar{R}^2$	d'[b]	Constant	Q'_{RE}/Q_{TL}	Q'_{M}/Q_{TL}	Q_{LF}/Q_{TL}	Q'_{O}/Q_{TL}	W	T
7	1910-39	0.90	1.56	0.66	0.69	0.042	-0.14	0.21	0.247	0.0019
		0.87			(0.44)	(0.098)	(0.15)	(0.16)	(0.069)	(0.0013)
8	1926-59	0.99	2.05	0.42	0.45	0.049	0.14	0.200	0.384	0.0028
		0.99			(0.21)	(0.060)	(0.10)	(0.071)	(0.064)	(0.0015)

[a]See text for source and composition of variables. All variables, except T, are in logarithms of original observations.

[b]The Durbin-Watson autocorrelation statistic d'.

volume" of input in 1947-49 dollars by splicing the two weighting periods on the basis of the overlapping values for 1940.

The independent variables are intended to provide a comprehensive coverage of all inputs used in agriculture in the current year. Limitations of least squares precludes inclusion of a large number of separate inputs in the production function. It is necessary to include items in Q_0', for example, which might be expected to have heterogeneous elasticities of production and, hence, do not fulfill the optimum aggregation criterion. It may be debated whether taxes should be included in the production function, since a lag occurs between payment of taxes and the resulting social input.

The independent variables explain a high portion of the variation in farm output and autocorrelation does not appear to be a problem based on the Durbin-Watson d' statistics (Table 1). The elasticity of production of the real estate input is about 0.4 or 0.5, consistently larger than other elasticities. Production elasticities of labor Q_{TL} and durables Q_D are low. If correct, the results indicate that an increase in labor or durables such as machinery, livestock and feed inventories would have little or no influence on farm output. The elasticity of production of the operating input variable is 0.3 or 0.4. Based on the known influence of fertilizer on crop yields and protein supplements on livestock production, it is not surprising to note the significant influence of operating inputs on output. The combined elasticities of two inputs, real estate and operating items, totals approximately 0.8 according to Table 1. If the hypothesis of constant returns is accepted for agriculture, other inputs would have a combined elasticity of approximately 0.2 and, therefore, only a small influence on output. The variables in Table 1 are highly correlated and the coefficients are sensitive to changes in specification. Therefore, caution is suggested in interpreting results.

Table 2 is an alternative specification. The quantities in the input variables are revised slightly, but more important, the input and output variables are specified per unit of labor. Even if the elasticity of product for labor is not zero, the revised specification does not necessarily lead to autocorrelation in the residuals. Consider the following logarithm production function 5 where X_3 is labor, Y is output per unit of labor, X_1 and X_2 are inputs per unit of labor, and u is the residual. The total, aggregate production function is

$$(5) \qquad X_3Y = b_0\,(X_3\,X_1)^{b_1}\,(X_3\,X_2)^{b_2}\,X_3^{b_3}\,u\,.$$

Estimating the production function on a per unit basis theoretically does not leave any component of X_3 for the residual if $b_1 + b_2 + b_3 = 1$, i.e. if the production function is homogeneous of degree one. Dividing equation 5 by X_3 we have

(6) $$Y = b_0\, X_1^{\,b_1}\, X_2^{\,b_2}\, X_3^{\,(b_1 + b_2 + b_3 - 1)}\, u.$$

If we have constant returns to scale, the exponent of X_3 equals zero, and the least squares estimate of equation 6 estimates have the desired properties (assuming equation 5 has these properties) even though b_3 is not equal to zero. Equations 7 and 8 in Table 8 are estimated to (a) increase the stability of the parameter estimates and (b) allow for the fixity of labor inputs in agriculture. The variables are defined as follows:

O/Q_{TL} Output of crops and livestock per unit of labor employed in agriculture (4, 118).

Q'_{RE}/Q_{TL} Real estate input Q'_{RE} less taxes per unit of labor (4, 118).

Q'_{M}/Q_{TL} Machinery input (interest and depreciation) per unit of labor (4, 118).

Q_{LF}/Q_{TL} Interest on productive livestock and feed inventories per unit of labor (4, 118).

Q'_{O}/Q_{TL} Input of Q'_{O} (defined above) per unit of labor (4, 118).

The weather W and time T variables are defined previously in Appendix A. All variables except T are logarithms of national aggregates for the current calendar year. Methods of aggregation were described earlier.

Equations 7 and 8, Table 2, indicate that the elasticity of production of real estate has declined. In general, the size of the elasticities are comparable to the estimates in Table 1. Again the responsiveness of output to inputs primarily is a function of real estate and operating inputs. The average productivity of livestock, feed and machinery is low according to equations 7 and 8.

Weather exerts a consistent influence on output. In all instances the coefficient is approximately 0.3 and significant. If the time coefficient is 0.002, the production function has shifted upward at approximately 0.5 percent per year. That is, the efficiency of farm inputs has in aggregate increased an average of one-half of one percent each year according to equations 5 and 7.

APPENDIX B: RELATIONSHIP BETWEEN NET FARM INCOME AND FARM PRICES

For many purposes, it is useful to be able to translate farm price changes into net income changes. The aggregate expression for net farm income Y may be defined as gross receipts less production expenses, or

$$Y_F = Q_R P_R - Q_P P_P \tag{1}$$

where Q_R is the quantity of farm products sold, P_R is prices received by farmers, Q_P is total farm inputs and P_P is prices paid for inputs. The price component is quite well defined in agriculture; the quantity relationship historically is more enigmatic. The relationship between Q_R and Q_P depends broadly on the aggregate input-output ratio and, hence, on weather and technology. Y_F is the return to durable assets and family labor, and to some extent, net income is a function of secular shifts in the level of durables.

With some adjustments, net income in equation 1 can be expressed as a function of farm prices P_R/P_P, the aggregate input-output or efficiency ratio T', weather W and the stock of productive assets S_P, i.e.

$$Y_F = f\ (P_R/P_P,\ S_p,\ W,\ T') \ . \tag{2}$$

The real price relationship in agriculture is an interaction between relative price and efficiency. This concept approximately is a ratio form of net income,

$$(3) \qquad Q_R P_R - Q_P P_P \overset{\text{(approx.)}}{=} (P_R/P_P)\ (Q_R/Q_P)$$

where $Q_R/Q_P = T'$. Since not all inputs are included in Q_P (Y_F is a residual income), it is well to include S_P in the definitional function to compensate for the conceptual discrepancy. The logic of equations 2 and 3 are combined in a new definitional model, including time subscripts

$$(4) \qquad Y_{Ft} = \phi\left[(T'\ P_R/P_P)_t,\ S_{pt},\ W_t,\ T'\right].$$

Other, slightly different forms might be used to represent the "real price" in parenthesis in equation 4. The variables providing the empirical foundation for the definitional equation are defined specifically as follows:

Y_{Ft} The net income of farm operators from farming during the current year, deflated by the index of prices paid by farmers for items used in production, interest, taxes and wage rates (120, 121). Net income includes cash receipts, government payments and non-money income less production expenses in millions of dollars.

$(P_R/P_P)_t$ The current year index of the ratio of prices received by farmers for crops and livestock to prices paid by farmers for items used in production, interest, taxes and wage rates, 1947-49 = 100 (120).

S_{pt} The beginning year stock of farm productive assets, in billions of 1947-49 dollars (4, 123).

W_t Stalling's index of the influence of weather on farm output in the current year (108, 124). Observations for 1958 and 1959 were not available from the original source, hence, were estimated from deviations from a linear yield trend.

T' The index of farm efficiency, the ratio of aggregate output to aggregate input in agriculture, 1947-49 = 100 (124).

T Time, an index composed of the last two digits of the current year.

Each equation was estimated from annual data from 1910 to 1959, omitting 1942 to 1945. The coefficients, standard errors and elasticities of the estimated equations are included in Table 1. The price variable P_R/P_P is included in several forms. Since the price responsiveness is expected to change from 1910 to 1959, two methods were used to accommodate the shifting price response. In equations 5, 6 and 7 three price variables are included. The first price variable contains actual prices from 1910 to 1925, zeros in other years. The two remaining price variables for these equations are specified similarly but with non-zero values of price for the 1926 to 1941 and 1946 to 1959 periods. Equation 8 contains price relationships as an interaction between price and T'. For any given value of T', the relationship between price and income may be estimated. Equations 5, 6 and 7 indicate

Table 1. Definitional equations relating net farm income to farm prices and ot
elasticities and other statistics are included for least squares esti
etc. with annual data from 1910 to 1959, excluding 1942 to 1945[a]

Equation[b]	R^2 and $\bar{R}^2$	d'[c]	Constant		(P_R/P_P) t (1910-25)	(P_R/P_P) t (1926-41)	(F (19
5	0.94	1.88	-1090	Coefficient	183.93	188.95	2
	0.93			Standard error	(12.85)	(14.51)	(
				Elasticity[d]	1.75	1.66	
6	0.94	1.58	-746	Coefficient	183.94	187.39	2
	0.93			Standard error	(13.12)	(14.78)	(
				Elasticity	1.75	1.65	
7	0.94	1.91	-3827	Coefficient	174.40	191.51	2
	0.93			Standard error	(12.68)	(15.16)	(
				Elasticity	1.66	1.68	
8	0.94	1.88	2411	Coefficient			
	0.93			Standard error			
				Elasticity			
9	0.93	1.29		Coefficient			
	0.92			Standard error			
				Elasticity			

[a]The form and composition of the variables are discussed in the text.

[b]All equations are linear in original observations.

[c]The Durbin-Watson autocorrelation statistic d'.

[d]The elasticities are computed at the means of the variables for the time

[e]The elasticities computed for the two-variable price model at the means o

farm prices and other variables; coefficients, standard errors (in parenthesis), least squares estimates of net farm income Y_F as a function of prices, weather, 1942 to 1945[a]

(P_R/P_P) t (1926-41)	(P_R/P_P) t (1946-59)	(P_R/P_P) t (1910-59)	$(T'P_R/P_P)$ t (1910-59)	S_P t	W t	T'	T
188.95 (14.51) 1.66	207.10 (11.25) 1.96			-177.57 (45.28) -1.51	32.23 (0.79)	54.08 (33.26) 0.45	83.14 (37.78)
187.39 (14.78) 1.65	209.46 (11.38) 1.98			-144.30 (41.22) -1.23	35.16 (9.82)		114.08 (33.32)
191.51 (15.16) 1.68	210.81 (11.65) 1.99			-147.66 (45.26) -1.26	31.01 (10.24)	90.95 (30.12) 0.75	
		105.66 (36.33) 0.87[e]	114.37 (37.85) --[e]	-177.68 (33.01) -1.51	30.05 (9.85)		95.96 (27.26)
		211.60 (10.43) 1.75		-118.75 (29.16) -1.01	35.16 (10.62)		165.72 (15.87)

in the text.

les for the time periods indicated.

el at the means of the time periods indicated are: 1910-25 ... 1.80
1926-41 ... 1.73
1946-59 ... 1.54.

that a one percent increase in P_R/P_P is associated with a two percent increase in Y_F in the 1946 to 1959 period. The estimate of elasticity for the same period from equation 8 is 1.54. The positive coefficients of the interaction terms in equation 8 indicate that the marginal response of income to price is increasing through time. But because the ratio of prices to net income is falling faster than the marginal response is rising, the elasticity is declining. All the equations in Table 1 indicate that the marginal response of income to prices is increasing. There is considerably less unanimity in the estimates of trends in elasticities, however. The implication is that a given price will result in a greater net income now than in the past.